Kemper County Storage Complex

Proposed Injection Well 19-2

Mississippi Power Company

Testing and Monitoring Plan

40 CFR 146.90

Facility Information

Facility Name:	Kemper County Storage Complex Well Name: MPC 19-2
Facility Contact:	Mississippi Power Company Environmental Affairs P.O. Box 4079 Gulfport, MS 39502-4079
Well Location:	Kemper County, Mississippi Latitude: 32.6130560 Longitude: -88.8061110

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List of Acronyms / Abbreviations

AoR	Area of Review
CCUS	Carbon capture, utilization, and storage
CO_2	Carbon dioxide
CMG	Computer Modelling Group
DOE	Department of Energy
ECO_2S	Establishing An Early Carbon Dioxide Storage
EPA	Environmental Protection Agency
ERRP	Emergency and Remedial Response
ft	feet
mg/L	milligrams per liter
MMt	Millions of Metric tons
MPC	Mississippi Power Company
PCC	Porters Creek Clay
PISC	Post-Injection Site Care
psi	Pounds per square inch
RCA	Routine Core Analysis
SS	Sub- Sea
TMS	Tuscaloosa Marine Shale
TVD	True Vertical Depth
UIC	Underground Injection Control
USDW	Underground Source of Drinking Water

A. Introduction

This *Testing and Monitoring Plan* describes how Mississippi Power Company (MPC) will monitor the Kemper County Storage Complex site, pursuant to guidance from rule 40 CFR 146.90, for the duration of the injection phase of this project. This plan will serve to demonstrate that the injection well is operating as planned, that the sequestered CO_2 plume and pressure front are moving as predicted and ensure that the CO_2 plume does not become a contamination risk to underground sources of drinking water (USDWs). Monitoring data collected will also be used to validate and adjust geologic models and reservoir simulations used to predict the movement of CO_2 within the storage zone to support the re-evaluation of the Area of Review (AoR) as needed.

The attachment to this *Testing and Monitoring Plan* exhibits a general schedule of testing and monitoring activities to be deployed throughout the life of the project. In the unlikely event of a leakage incident or anomalous analytical result obtained from testing and monitoring activities, action may be triggered according to the *Area of Review and Corrective Action Plan*, the *Emergency and Remedial Response Plan*, and/or additional response procedures if needed. A *Quality Assurance and Surveillance Plan* (QASP) for all testing and monitoring activities per 146.90(k) is provided as Attachment to this permit. Mississippi Power Company will submit testing and monitoring activity results to EPA as required under 40 CFR 146.91.

B. Strategy and Approach for Testing and Monitoring

The Kemper County Storage Complex *Testing and Monitoring Plan* relies heavily on a well-based monitoring program. The proposed plan will draw samples from five wells that have been perforated in the injection zone and two wells perforated above the storage zone in deep saline aquifers. Seven monitoring wells have been perforated in the deep USDW intervals and will also monitor shallow groundwater. The deep in-zone monitoring wells will be placed at distances outside of the expected plume footprint to provide pressure data about the plume extent to provide detailed comparisons to the heterogenous geologic data in order to build confidence in the forward modeling results. Pressure data and saturation logging gathered from the deep wells are industry tested and robust monitoring technologies that provide excellent data for comparison to numerical modelling results of the CO_2 plume migration. Given our understanding of the injection zone geology, with exceptionally high porosity, permeability, lateral continuity, and relatively simple structure (see *Application Narrative*), we expect the CO_2 plume to spread outward from the injection well, with relatively thin edges and then slowly migrate updip (see *Area of Review and Corrective Action Plan*). The deployment of 3D seismic is logistically difficult at the

Kemper County Storage Complex given the surface topography, including forested areas and wetlands as a result it is believed that well-based measurements will provide exceptional resolution of the subsurface plume development based on the data and results collected from the Citronelle storage test in Alabama [1]. The frequency and availability of the well-based monitoring data, in particular the pressure data from multiple in-zone wells, will allow for early indications of subsurface behavior that may be inconsistent with forward modeling simulations.

The *Testing and Monitoring Plan* for the Kemper County Storage Complex is designed to ensure that measurable quantities of injected CO_2 will not escape from the sequestration reservoir. Monitoring data will be collected and used to validate rigorous numerical modeling performed during the planning and characterization phase of the project. This model, being the primary method of forecasting the position and characteristics (pressure and saturation) of injected CO_2 within the storage complex, will ultimately support and demonstrate that injection activities will not pose a risk for contamination of any proximal underground sources of drinking water (USDWs) over the life of the project.

MPC recognizes the process of data collection and modeling as the primary pathway to exit the regulatory permit, define the post-injection site care (PISC) protocols, and close the CO_2 storage project as noted in the EPA's Underground Injection Control (UIC) Class VI regulations (CFR 40 146.92). As such, MPC proposes to establish a monitoring program to validate that injected CO_2 remains in the storage complex throughout the life of the project. Data will be collected using the following reliable subsurface monitoring protocols:

- Above-zone and in-zone measurements
- Periodic water brine sampling
- Through-casing CO_2 saturation monitoring
- Physical and mechanical equipment integrity testing
- Repeat injection flow profile surveys
- Shallow/deep USDW water geochemistry sample monitoring

[1] Esposito, R. A., Pashin, J. C., Hills, D. J., & Walsh, P. M. (2010). Geologic assessment and injection design for a pilot CO2-enhanced oil recovery and sequestration demonstration in a heterogeneous oil reservoir: Citronelle Field, Alabama, USA. Environmental Earth Sciences, 60(2), 431-444.

These monitoring protocols will provide valuable information to evaluate the performance of injection and storage operations over time. This plan describes components of the testing and monitoring program which includes hydraulic, geophysical, and geochemical components for characterizing the complex transport processes associated with CO_2 injection and storage. **Table 1** details the monitoring methods and baseline frequencies that will be implemented for the monitoring wells at the Kemper County Storage Complex. Data will be collected from both injection and monitoring wells within the target injection interval (Paluxy Formation) for the duration of the project. Two deep monitoring wells above the injection interval will serve as early detection vectors and will be installed within the deepest permeable and porous portion of the reservoir that lies directly above the primary confining zone (Tuscaloosa Marine Shale). In the unlikely event there is a loss of containment, monitoring in this interval above the injection zone should serve as an early detection signal, triggering actions within the *Emergency and Remedial Response Plan*.

In the unlikely event of a detected containment loss, a modeling evaluation of any observed CO_2 migration above the confining zone would be used to assess the magnitude of such loss and make bounding predictions regarding the expected impacts on shallower intervals and ultimately, the potential for adverse impacts on USDWs. Comparison of observed and simulated arrival responses at the early-detection wells and shallower monitoring locations will continue throughout the life of the project and will be used to calibrate and verify the model through time, while improving the model's predictive capability.

Table 1: Monitoring Methods and Baseline Frequencies

Monitoring Category	Monitoring Method	Baseline Frequency	Injection Phase Frequency (30 years)	Post-Injection Frequency (20 years)
Monitoring Plan Update	N/A	As required	As required	As required
CO_2 Injection Stream Monitoring	Grab Sampling and Analysis	Quarterly, beginning at least 6 months prior to injection	Quarterly	N/A
CO_2 Injection Process Monitoring	Continuous monitoring of injection process (Injection rate, pressure, and temperature; annulus pressure and volume)	N/A	Continuous	N/A
Mechanical Integrity Testing	Injection well pressure fall-off testing PNC logging, temperature logging	Once after well completion Once after well completion	Once every 3 years minimum Annually	N/A N/A
Corrosion Monitoring of Well Materials	Corrosion coupon testing Wireline monitoring of casing and/or tubing corrosion and cement	N/A Once after well completion	Quarterly Once every three years or during well workovers	N/A N/A
Groundwater Quality and Geochemistry Monitoring (Above-Zone)	Early leak-detection in above-zone monitoring wells (fluid sampling) Deep USDW monitoring and shallow groundwater monitoring (fluid sampling)	3 events prior to injection 3 events prior to injection	Annually Annually	Annually Annually
Pressure Monitoring	Early leak-detection in above-zone monitoring wells In-zone monitoring wells and injection wells	Once after well completion Once after well completion	Continuous Continuous	Continuous Continuous
Direct Plume Monitoring (In-zone)	Fluid sampling in the four in-zone monitoring wells	3 events prior to injection	Annually until CO_2 plume is confirmed	Annually until CO_2 plume is confirmed
Indirect Geophysical Monitoring Techniques (wireline logging)	PNC/RST logging, temperature logging in the two injection wells, four in-zone monitoring wells, and two above-zone monitoring wells Flow profile surveys in the two injection wells	Once after well completion prior to injection N/A	Annually Annually	Every 2 years N/A

C. Carbon Dioxide Stream Analysis

MPC will analyze the CO_2 stream during the operation period to yield data representative of its chemical and physical characteristics, per the requirements of 40 CFR 146.90(a). Based on analysis from Southern Company's CO_2 injection demonstrations at Plant Daniel in Jackson County, Mississippi, and Plant Barry in Mobile County, Alabama, MPC expects the CO_2 stream that will be injected at the Kemper County Storage Complex to have the following composition:

- CO_2 99.4 %
- H_2S << 100 ppm (<< 0.01 %)
- N_2 0.3 %
- CH_4/C_2H_6 0.3%

C.1. Sampling location and frequency

MPC will analyze the CO_2 stream during the operations period to monitor its chemical and physical characteristics as required by 40 CFR 146.90(a). Once baseline parameters are established, testing and analysis will occur quarterly to ensure that the chemical and physical characteristics of the CO_2 stream remain as expected. Stream analysis will begin six months prior to the start of CO_2 injection operations. MPC will increase frequency of CO_2 stream composition sampling in the event that unexpected chemical and physical characteristics are observed at any time during routinely scheduled sampling and analysis.

The CO_2 samples will typically be analyzed for the following constituents shown in **Table 2** below. The list of parameters to be analyzed may be altered if analysis from the CO_2 stream demonstrates additional constituents to be considered.

In the event of unplanned disruptions to permitted injection activities, MPC will modify the existing sampling schedule to ensure that there are no significant changes in the CO_2 stream chemical and physical characteristics prior to resuming injection operations. In such a scenario, MPC would inform and report additional sampling activities and results to the regional EPA director overseeing this project.

C.2. Analytical parameters

MPC will analyze CO_2 samples for the constituents identified in **Table 2** using the methods listed. Sampling will begin no later than six months prior to the start of CO_2 injection, after which CO_2 stream composition sampling and analysis will occur quarterly.

Table 2: Summary of analytical parameters for CO_2 stream.

Parameter	Analytical Method(s)
Oxygen	ISBT 4.0 (GC/DID) GC/TCD
Nitrogen	ISBT 4.0 (GC/DID) GC/TCD
Carbon Monoxide	ISBT 5.0 Colorimetric ISBT 4.0 (GC/DID)
Oxides of Nitrogen	ISBT 5.0 Colorimetric
Methane	ISBT 10.1 (GC/FID)
Sulfur Dioxide	ISBT 14.0 (GC/FID)
Hydrogen Sulfide	ISBT 14.0 (GC/FID)
CO_2 Purity	ISBT 2.0 Caustic absorption Zahm-Nagel ALI method SAM 4.1 subtraction method (GC/DID) GC/TCD

C.3. Sampling methods

CO_2 stream sampling will occur in the compressor building after the last stage of compression and prior to injection. A sampling station will be installed with the ability to purge and collect samples into a container that will be sealed and sent to the authorized laboratory.

All sample containers will be labeled with a unique sample identification number and sampling date, which will then be logged into a database. Additional details regarding the specific procedures related to sample collection and analysis are detailed in the *Quality Assurance and Surveillance Plan* of this permit.

C.4. Laboratory to be used/chain of custody and analysis procedures

Samples will be analyzed by a third-party laboratory using standardized procedures for gas chromatography, mass spectrometry, detector tubes, and photo ionization. The sample chain-of-custody procedures described in Section B.3.e of the *Quality Assurance and Surveillance Plan* will be employed.

D. Continuous Recording of Operational Parameters

MPC will install and use continuous recording devices to monitor injection pressure, rate and volume; the pressure on the annulus between the tubing and the long string casing; the annulus fluid volume added; and the temperature of the CO_2 stream, as required at by 40 CFR 146.88(e)(1), 146.89(b), and 146.90(b). All monitoring will be continuous for the duration of the operation period. Parameters, device, location, and sampling frequency are outlined in **Table 3** below.

Table 3: Sampling devices, locations, and frequencies for continuous monitoring.

Parameter	Device(s)	Location	Min. Sampling Frequency (active / shut-in)	Min. Recording Frequency (active / shut-in)
Injection Pressure Monitoring	Surface Injection Pressure Gauge	Surface	5 sec. / 4 hours	5 mins. / 4 hours
Injection Rate Monitoring	Flow Meter (SCADAsense)	Surface	5 sec. / 4 hours	5 mins. / 4 hours
Injection Volume Monitoring	Coriolis Flow Meter	Surface	5 sec. / 4 hours	5 mins. / 4 hours
Annular Pressure Monitoring	Continuous Annular Pressure Gauge, annulus fluid reservoir, pressure regulators, tank fluid indication	Surface	5 sec. / 4 hours	5 mins. / 4 hours
Casing and Tubing Pressure Monitoring	Continuous Surface Pressure Gauge	Surface	5 sec. / 4 hours	5 mins. / 4 hours
Annulus Fluid Volume Monitoring	Continuous Surface Pressure Gauge	Surface	5 sec. / 4 hours	5 mins. / 4 hours
CO_2 Stream Temperature Monitoring	Surface Temperature Gauge	Surface	5 sec. / 4 hours	5 mins. / 4 hours

Notes:

- Sampling frequency refers to how often the monitoring device obtains data from the well for a particular parameter. For example, a recording device might sample a pressure transducer monitoring injection pressure once every two seconds and save this value in memory.

- Recording frequency refers to how often the sampled information is recorded to digital format (such as a computer hard drive). For example, the data from the injection pressure transducer might be recorded to a hard drive once every minute.

Above-ground pressure and temperature instruments shall be calibrated over the full operational range at least annually using American National Standards Institute (ANSI) or other industry recognized standards. Pressure transducers shall have a drift stability of less than 1 psi over the operational period of the instrument and an accuracy of ± 5 psi. Sampling rates will be at least once every 5 seconds. Temperature sensors will be accurate to within one degree Celsius.

Injection rate (flow) will be monitored with a Coriolis mass flowmeter at the compression facility. The flowmeter will be calibrated for the entire expected range of flow rates using generally accepted standards and is accurate to within ± 0.1 percent.

D.1. Injection Rate and Pressure Monitoring

MPC will monitor injection operations using a distributive process control system (DPCS). The Surface Facility Equipment & Control System will limit maximum flow to 4,338 metric tons per day and/or limit the well head pressure to 2,380 psig, which corresponds to the regulatory requirement to not exceed 90% of the injection zone's fracture pressure. All critical system parameters (e.g., pressure, temperature, and flow rate) will have continuous electronic monitoring with signals transmitted back to a master control system. The system will sound an alarm and shutdown operations, should specified control parameters exceed their normal operating range at any time. MPC supervisors and operations personnel will have the capability to monitor the status of the system comprehensively from distributive control centers. Primary monitoring stations will be in the phase 1 compression control room near the CO_2 collection and blower facility, and phase 2 main compression control room.

D.2. Pressure Monitoring

MPC will use the procedures below to monitor annular pressure. The following procedures will be used to minimize the potential for any unpermitted fluid movement into or out of the annulus:

1. The annulus between the tubing and the long string of casing will be filled with brine. The brine will have a specific gravity of 1.06 and a density of 8.85 lbs/gal. The hydrostatic gradient is 0.46 psi/ft. The brine will contain a corrosion inhibitor.

2. The surface annulus pressure will be kept at a minimum of 200 psi during injection.

3. During periods of well shut down, the surface annulus pressure will be kept at a minimum pressure to maintain a differential of at least 100 psi between the annular fluid directly above (higher pressure) and below (lower pressure) the injection tubing packer set at a depth of 5,000 ft.

4. The pressure within the annular space, in the interval above the packer to the confining layer, will be kept greater than the pressure of the injection interval (Paluxy Formation) at all times.

5. The pressure in the annular space directly above the packer will be maintained to at least 100 psi higher than the adjacent tubing pressure during injection.

Figure 1 below shows the process instrument diagram for the injection well annulus protection system. The annular monitoring system consists of a continuous annular pressure gauge, a pressurized annulus fluid reservoir (annulus head tank), pressure regulators, and tank fluid level indicator. The annulus system will maintain annulus pressure by controlling the pressure on the annulus head tank using either compressed nitrogen or CO_2.

The annulus pressure will be maintained to between 200-250 psi as it is monitored by the MPC control system gauges. The annulus head tank pressure will be controlled by pressure regulators; one set of regulators to maintain pressure above 200 psi by adding compressed nitrogen or CO_2 and the other to relieve pressure above 250 psi by venting gas from the annulus head tank. Any changes to the composition of annular fluid will be included in the next report and submitted to the permitting agency.

If system communication were to be lost for greater than 30 minutes, project personnel will observe and monitor manual gauges in the field every four hours or twice per shift for both wellhead surface pressure and annulus pressure, while also recording hard copies of the data until communication is restored.

Average annular pressure, annulus tank fluid level, and volume of fluid added or removed from the system will be recorded daily.

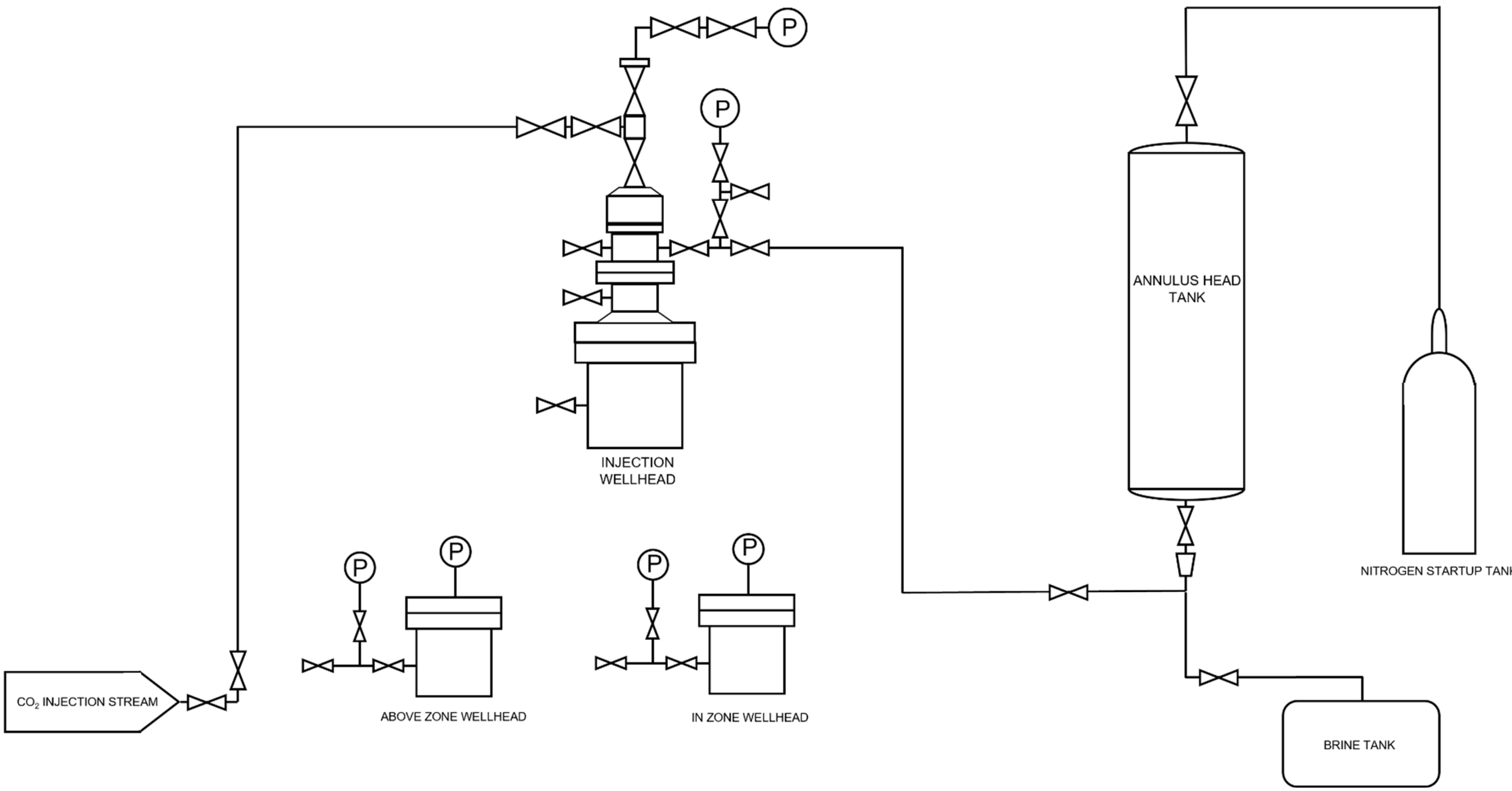

Figure 1: Annular Monitoring System General Layout

The casing-tubing pressure will be monitored and recorded in real time. Pressure of the casing-tubing annulus is anticipated to be no lower than 200 psi. Any significant change of casing-tubing annulus pressure that may be related to mechanical integrity issues will be investigated as a possible leak in one of four areas:

1. Casing - from the surface to the packer
2. Tubing string - from the surface to the packer
3. Packer seal
4. Tree

Surface pressure of the casing-tubing annulus is anticipated to be from 200 to 250 psi. As detailed in the *Emergency and Remedial Response Plan*, significant changes in the casing-tubing annular pressure attributed to well mechanical integrity will be investigated. Collection and recording of monitoring data will occur at the frequencies described in **Table 1**.

D.3. Tubing Pressure Monitoring

During the injection phase of the project, the tubing pressure will be monitored and recorded in real time. Surface pressure of the tubing annulus is anticipated to be from 200 to 250 psi. As detailed in the *Emergency and Remedial Response Plan*, significant changes in the casing-tubing annular pressure attributed to well mechanical integrity will be investigated.

E. Corrosion Monitoring

To meet the requirements of 40 CFR 146.90(c), MPC will monitor well materials during the operation period for loss of mass or thickness, and any evidence of cracking, pitting, or other signs of corrosion to ensure that the well components meet the minimum standards for material strength and performance. MPC will monitor corrosion to casing and tubing using corrosion coupons. Methodology for sample collection is described below.

E.1. Monitoring location and frequency

Corrosion monitoring coupons consisting of well casing and tubing materials will be placed in the CO_2 pipeline. Each coupon will be made of the same material as the long string casing and the injection tubing. The coupons will be removed quarterly and assessed for corrosion using ASTM G1-03 or similarly accepted standard practice for preparing, cleaning, and evaluating corrosion test specimens. Upon removal, coupons will be inspected visually for evidence of corrosion. The weight and size (thickness, width, length) of the coupons will be measured and recorded.

The corrosion rate will be calculated as the weight loss during the exposure period divided by the duration (i.e., weight loss method).

In addition to the Class VI UIC protocols that require quarterly coupon testing, MPC will employ additional techniques to ensure containment and guard against corrosion, including annual cased hole pulsed neutron logs (e.g., PNC logs), annual flow profile surveys, noise and ultrasonic cement bond logs as necessary, annual mechanical integrity testing (MIT), and real-time annular pressure monitoring.

Casing and tubing will be evaluated annually for corrosion throughout the life of the injection well by running wireline casing inspection logs (CILs). The frequency of running these tubing and casing inspection logs may be adjusted based on site-specific parameters and well performance.

Wireline tools will be lowered into the well to directly measure properties of the well tubulars that indicate corrosion. These tools, which may be used to monitor the condition of well tubing and casing, include:

- Mechanical casing evaluation tools, referred to as calipers, which have multiple articulated arms attached to the tool that measure the inner diameter of the tubular as the caliper is raised or lowered through the well.
- Ultrasonic tools, which are capable of measuring wall thickness in addition to the inner diameter of the well tubular and can also provide information about the outer surface of the casing or tubing.

- Electromagnetic tools, which are capable of distinguishing between internal and external corrosion effects using variances in the magnetic flux of the tubular being investigated. These tools are able to provide circumferential images with high resolution such that pitting depths, due to corrosion, can often be accurately measured.

E.2. Sample description

Samples of material used in the construction of compression equipment, pipelines, and injection wells which will directly contact the CO_2 stream will be included in the corrosion monitoring program by either using actual material and/or conventional corrosion coupons. The samples consist of those items listed in **Table 4** below. Each coupon will be weighed, measured, and photographed prior to initial exposure.

Each sample will be attached to an individual holder and then inserted in a flowthrough pipe arrangement. The corrosion monitoring system will be located downstream of all process compression, dehydration, and pumping equipment (i.e., at the beginning of the pipeline to the wellhead). To accomplish this, a parallel stream of high-pressure CO_2 will be routed from the pipeline through the corrosion monitoring system and then back into a lower pressure point upstream in the compression system. This loop will operate any time injection is occurring, providing representative exposure of the samples to the CO_2 composition, temperature, and pressures that will be seen at the wellhead and injection tubing. The holders and location of the system will be included in the pipeline design and will allow for continuation of injection during sample removal.

Table 4: List of equipment coupon with material of construction.

Equipment Coupon	Material of Construction
Pipeline	API 5L X42 PSL2 or API 5L X52 PSL2 carbon steel
Long String Casing	13% Chromium Stainless Steel
Injection Tubing	13% Chromium Stainless Steel
Wellhead	13% Chromium Stainless Steel
Packers	13% Chromium Stainless Steel

E.3. Sample Monitoring and Handling

Coupons will be handled and assessed for corrosion using the American Society for Testing and Materials ASTM G1-03 or similar standard practice for preparing, cleaning, and evaluating corrosion test specimens. The coupons will be photographed, visually inspected with a minimum of 10x power, dimensionally measured (to within 0.0001 inch), and weighed (to within 0.0001 gm).

F. Groundwater Quality and Geochemistry Monitoring Above Confining Zone

MPC will monitor ground water quality and geochemical changes above the confining zone during the operation period to meet the requirements of 40 CFR 146.90(d). The purpose of such monitoring is to detect any measurable CO_2 migration out of the injection zone before it can result in any impacts on USDW aquifer water quality.

To meet the requirements at 40 CFR 146.95(f)(3)(i), MPC will also monitor ground water quality, geochemical changes, and pressure in the first known potential USDW immediately above the primary confining zone (Tuscaloosa Marine Shale) as well as shallower ground water drinking sources.

Direct monitoring of aqueous chemistry and related field parameters will be used to detect and quantify any potential impacts on USDW aquifers from any breach of hypersaline waters and/or CO_2 from the injection zone. Monitoring locations will include intervals immediately above the primary confining zone for early leak-detection (i.e., Above-Zone (AZ) monitoring wells) and shallower USDW aquifer monitoring.

The groundwater monitoring plan focuses on the following zones:

- **Middle and Lower Wilcox (Eocene-aged)** – shallowest USDW source.
- **Eutaw-McShan Formation (Upper Cretaceous),** including Eutaw-McShan,– representing the lowermost potential USDW with total dissolved solids (TDS) reported ~1,600 – 10,000 ppm.
- **Upper Tuscaloosa Sand** – the zone directly above the primary confining zone (Tuscaloosa Marine Shale).

In addition to the extensive coverage that the deep USDW and shallow groundwater monitoring wells provide, MPC's testing and monitoring design additionally satisfies the requirements of 40 CFR 146.90 (d), where groundwater samples will be collected and analyzed from the zone directly above the confining zone (i.e., Upper Tuscaloosa Sand) positioned between the primary confining zone (e.g., Tuscaloosa Marine Shale) overlying the injection zone and the lowermost potential USDW aquifer (i.e., Upper Cretaceous).

Pressure and aqueous monitoring requirements for the above zone monitoring wells, including the general monitoring approach, the list of targets for analysis, and the analytical and quality assurance requirements are all discussed in the Sampling and Analysis Section below. Once CO_2 injection begins, aqueous monitoring will be conducted on a regular basis to monitor potential upward migration of CO_2 out of the targeted injection zone. It is expected that any potential leaks will take time to develop and travel upwards, and therefore any measurements from the above-zone, deep water, and shallow water monitoring wells should still be within range of baseline values when the monitoring phase begins. As such, there is no need for separate baseline monitoring in these wells prior to injection. Direct monitoring of aqueous chemistry and related field parameters will be used to detect and quantify any potential impacts on USDW aquifers resulting from potential injection zone containment loss. Given the depth of the targeted injection interval (Paluxy at >5,000 ft), the expected integrity of the overlying, primary confining zone/seal (Tuscaloosa Marine Shale) unit, the presence of the secondary confining intervals between the injection interval and confining zone (e.g., Basal and Upper Wash-Fred Shales), the presence of two additional prospective injection zones (Massive Sand and Wash-Fred), and the lack of any known preferential pathways between the injection zone and USDW aquifers (see *Application Narrative*), the likelihood of CO_2 coming into direct contact with the lowermost USDW aquifer within the Upper Cretaceous formations, and the resulting impacts on water quality associated with such an occurrence are perceived to be very low.

If a significant breach in the primary confining zone were to occur during injection operations, the above-zone early-leak-detection monitoring vectors in the Upper Tuscaloosa should identify the leak and allow for the implementation of mitigation strategies well before any impacts on the overlying USDW aquifers can occur. However, to ensure that the local drinking water supply is adequately protected, a comprehensive USDW monitoring program will be instituted.

The current design of the groundwater monitoring network above the confining zone infers that there are increasing salinity and TDS concentrations as depth increases in the subsurface of the Kemper County Storage Complex. These inferences will be confirmed with additional and on-going characterization efforts that are currently underway.

F.1. Monitoring of lowermost USDW

Monitoring groundwater quality in USDW aquifers is required by 40 CFR 146.90. The intended purpose of this type of monitoring is to detect and quantify any potential impacts of CO_2 containment loss on the water quality of local drinking water aquifers.

Direct monitoring of the lowermost USDW aquifer is required by the EPA's UIC Class VI GS Rule (75 FR 77230). A network of both deep potential USDW and shallow ground water monitoring locations will be used to provide a thorough assessment of baseline conditions at the site and a spatially distributed monitoring scheme that can be routinely sampled throughout the life of the project. See **Figure 2** below.

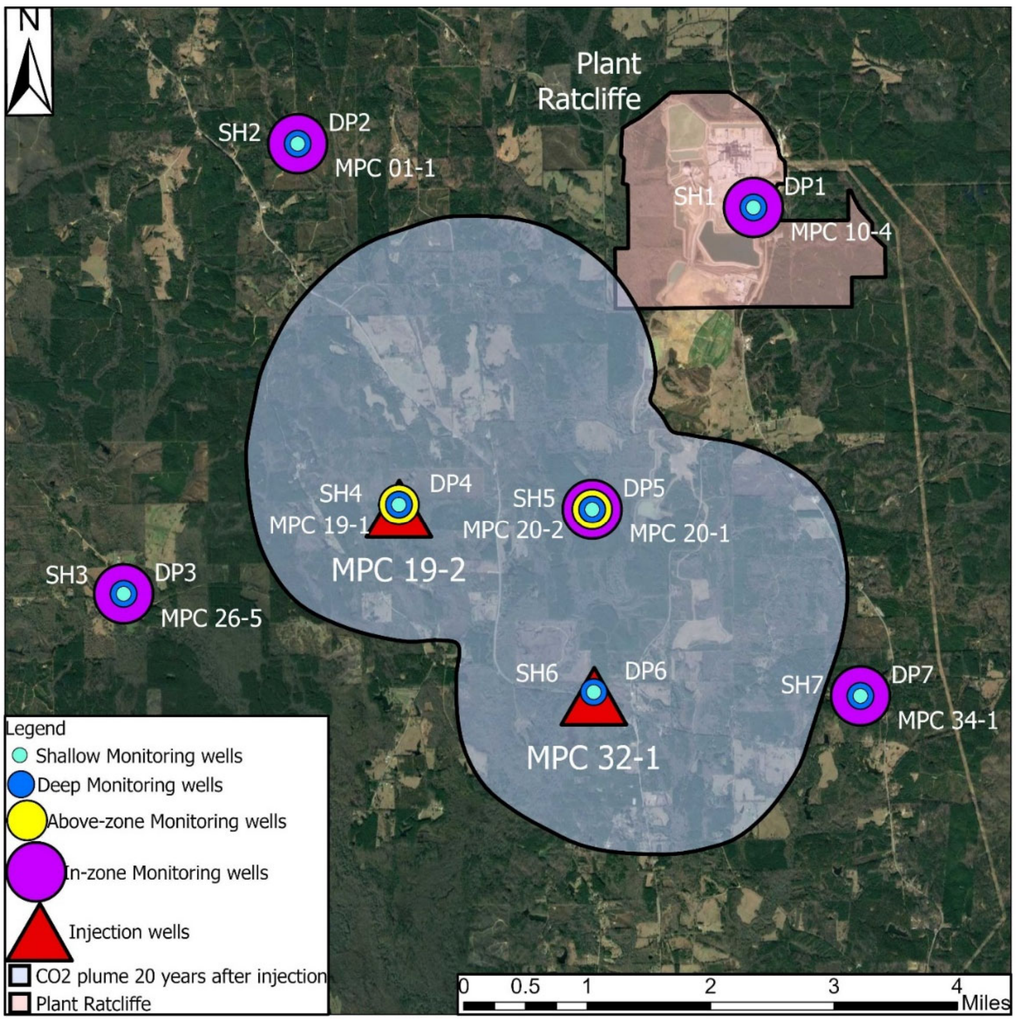

Figure 2: Location map showing monitoring well network with predicted CO_2 plume.

Seven deep wells will be monitored by regularly collecting fluid samples from Upper Cretaceous formations such as the Eutaw-McShan, Gordo and Coker (lowermost potential USDW aquifers). Seven additional shallow ground water wells completed in the Middle/Lower Wilcox (shallowest ground water aquifer) will also be monitored to help ensure non-endangerment to any USDW or groundwater aquifers.

The Testing and Monitoring network design at the Kemper County Storage Complex consists of the following injection and monitoring wells:

- **CO_2 Injection Wells (MPC 19-2 and MPC 32-1)**. Two CO_2 injection wells located in the southern portion of the Kemper County Storage Complex will be drilled and completed in the Paluxy Formation and spaced roughly two miles apart. The placement of these two CO_2 injection wells is based on the regional geologic study that has been completed as part of the characterization phase of this project. Modeling projects that the CO_2 plume will partially migrate up-dip in the northeast direction, given the gentle southwest trending dip setting that is observed in the subsurface across the storage complex.
- **In-Zone Pressure and CO_2 Plume Monitoring Wells (MPC 01-1, MPC 10-4, MPC 26-5, MPC 20-1, and MPC 34-1)**. Five In-Zone pressure monitoring wells are located at various distances from the two CO_2 injection wells. Some of these In-Zone pressure and plume monitoring wells were drilled during the regional and local Site Characterization phases of the project. They are equipped with tubing, packers, and pressure gauges and are perforated in the Paluxy Formation.
- **Monitoring Wells Above the Primary Confining Interval (MPC 19-1 and MPC 20-2).** Two Above-Zone Monitoring wells will be drilled and completed in the Upper Tuscaloosa Sand, which directly overlies the primary confining zone (Tuscaloosa Marine Shale). The two above-zone monitoring wells will continuously monitor pressure via surface gauges and will also conduct annual fluid sampling during the injection phase of the project.
- **Deep USDW Monitoring Wells (DP-1, DP-2, DP-3, DP-4, DP-5, DP-6 and DP-7).** Seven Deep USDW Monitoring wells will be completed in the Upper Cretaceous Eutaw Formation, where potential USDW aquifers with reported TDS concentrations of ~3,000 mg/L are observed. In addition to baseline sample collection and analysis prior to the start of injection, fluid samples will be collected annually from each monitoring well during the injection phase.

- **Shallow Ground Water Monitoring Wells (SH-1, SH-2, SH-3, SH-4, SH-5, SH-6, and SH-7).** Seven Shallow Ground Water wells will be completed in the local shallow USDW, within the Eocene-Aged formations, including the Middle/Lower Wilcox group. In addition to baseline sample collection and analysis prior to the start of injection, fluid samples will be collected annually from each of these wells during the injection phase of the project.

F.2. Monitoring location and frequency

Table 5 lists the planned monitoring methods, locations as shown in **Figure 2**, and frequencies for ground water quality and geochemical monitoring above the confining zone.

Table 5. Monitoring of ground water quality and geochemical changes above confining zone.

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
Middle and Lower Wilcox (Eocene)	Shallow groundwater sampling	Shallow groundwater monitoring wells; SH-1, SH-2, SH-3, SH-4, SH-5, SH-6, SH-7	7 point locations; 1 sampling interval each. Approx. Depth for the Wilcox Group is ground surface	Baseline (at least 3 samples prior to injection); Annually during the injection phase (30 years)
Eutaw-McShan (Upper Cretaceous)	Deep USDW groundwater sampling	Deep USDW monitoring wells; DP-1, DP-2, DP-3, DP-4, DP-5, DP-6, DP-7	7 point locations; 1 sampling interval each. Approx. Depths: DP-1: 2000 ft DP-2: 2150 ft DP-3: 2200 ft DP-4: 2150 ft DP-5: 2100 ft DP-6: 2100 DP-7: 2100 ft	Baseline (at least 3 samples prior to injection); Annually during the injection phase (30 years)
Upper Tuscaloosa Sand	Reservoir fluid sampling	Above-Zone monitoring wells; MPC 19-1, MPC 20-2	2 point locations; 1 sampling interval each. Approx. Depths: MPC 20-2: 3200 ft MPC 19-1: 3300 ft	Baseline (at least 3 samples prior to injection); Annually during the injection phase (30 years)
	Pressure monitoring	Above-Zone Confining Wells; MPC 19-1 MPC 20-2	1 point location; 1 interval each: MPC 20-2: 3200 ft MPC 19-1: 3300 ft	Continuous

MPC will also collect one baseline, pressurized fluid sample from the Paluxy Formation injection interval from the MPC 19-2 well in accordance with EPA Class VI requirement 40 CFR 146.87(b), requiring the collection of fluid samples from the injection interval prior to injection well operation. The fluid samples previously collected from the Paluxy Sandstone in MPC 10-4 and the new sample from the MPC 19-2 will enable MPC to establish baseline reservoir fluid sampling conditions prior to injection operations. Fluid samples will be collected and analyzed from the five in-zone monitoring wells on an annual basis. Details regarding in-zone fluid sampling are discussed later in this section under CO_2 plume and pressure monitoring activities. See **Table 1** above for the specific monitoring activities and frequencies that will occur at each well.

MPC will use indirect monitoring techniques (including PNC and temperature logs) in the two above-zone monitoring wells to compliment the direct fluid sampling analysis discussed in this section. These indirect monitoring techniques will provide additional data to compare against fluid sampling results in the event that abnormal or unexpected results are detected during geochemical monitoring above the confining zone. PNC and temperature logs will be run on an annual basis during the injection phase.

F.3. Analytical parameters

Table 6 identifies the parameters to be monitored and the analytical methods MPC will employ when collecting and analyzing groundwater sampling results.

Table 6: Summary of analytical and field parameters for ground water samples.

Parameters	Analytical Methods
Middle and Lower Wilcox (Eocene)	
Cations: Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb, Se, and Tl	ICP-MS, EPA Method 6020
Cations: Ca, Fe, K, Mg, Na, and Si	ICP-OES, EPA Method 6010B
Anions: Br, Cl, F, NO_3, and SO_4	Ion Chromatography, EPA Method 300.0
Dissolved **CO_2** Total Dissolved Solids Alkalinity pH (field) Specific conductance (field) Temperature (field)	Coulometric titration, ASTM D513-11 Gravimetry, APHA 2540C APHA 2320B EPA 150.1 APHA 2510 Thermocouple

Parameters	Analytical Methods
Eutaw-McShan (Upper Cretaceous) (Deep USDWs) and Upper Tuscaloosa Sand (Above-Zone)	
Cations: Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb, Se, and Tl	ICP-MS, EPA Method 6020
Cations: Ca, Fe, K, Mg, Na, and Si	ICP-OES, EPA Method 6010B
Anions: Br, Cl, F, NO_3 and SO_4 Dissolved **CO_2**	Ion Chromatography, EPA Method 300.0 Coulometric titration, ASTM D513-11
Isotopes: S13C of DIC	Isotope ratio mass spectrometry
Total Dissolved Solids Water Density Alkalinity pH (field) Specific conductance (field) Temperature (field)	Gravimetry, APHA 2540C Oscillating body method APHA 2320B EPA 150.1 APHA 2510 Thermocouple

F.4. Sampling methods

Sampling will be performed as described in the *Quality Assurance and Surveillance Plan (QASP)*. The QASP section describes the groundwater sampling methods to be employed, including sampling standard operating procedures and sample preservation.

F.5. Laboratory to be used/chain of custody procedures

Sample handling and custody will be performed as described in the QASP Section. Quality control will be ensured using the methods described in the QASP Section.

G. External Mechanical Integrity Testing (External and Internal)

MPC will conduct at least one of the tests presented below in **Table 7** periodically during the injection phase to verify external mechanical integrity tests (MIT) as required at 146.89(c) and 146.90.

Mechanical integrity will be evaluated to ensure that infrastructure remains sound for the life of the well. The absence of any leaks in the casing, injection tubing, and packer will be demonstrated using annulus pressure tests that will be conducted annually. The condition of the cement and casing will be verified using downhole logging techniques and tools. An ultrasonic cement bond inspection log will be run through the entire length of the long-string casing once every five years, and additionally during periods when the injection tubing is removed from the well for maintenance or other testing. An electromagnetic casing inspection log will be run on the same schedule as the cement inspection log. The casing inspection log will be used to determine the thickness, external condition, and internal condition of the long string casing for its entire length. PNC logs will be run at least one year prior to the start of CO_2 injection and annually during injection to identify any potential fugitive CO_2 movement. Notice of intent to conduct pressure tests, temperature logs, and any additional mechanical tests, logs, or inspections will be provided at least thirty (30) days prior to the demonstration of mechanical integrity.

Table 7. Showing MIT test description, location, and frequency.

Test Description	Location	Frequency During Injection Phase
Pressure Fall-off Testing	CO_2 Injection Well(s)	Minimum of once per 3 years, during planned well maintenance
Annulus Pressure Test	CO_2 Injection Well(s)	Annually
Annulus Pressure Monitoring	CO_2 Injection Well(s)	Continuous recording
Pulsed Neutron Capture (PNC) Log	CO_2 Injection Well(s), Four In-Zone Monitoring Wells, Two Above-Zone Monitoring Wells	Annually
Temperature Logging	CO_2 Injection Well(s), Four In-Zone Monitoring Wells, Two Above-Zone Monitoring Wells	Annually
Ultrasonic Cement Bond Inspection Log	CO_2 Injection Well(s)	Minimum of once every 5 years
Electromagnetic Casing Inspection Log	CO_2 Injection Well(s)	Minimum of once every 5 years

G.1. Testing location and frequency

In accordance with 40 CFR 146.89(b), MPC will conduct an initial annulus pressure test prior to the start of CO_2 injection. Subsequent tests will be conducted annually in accordance with US EPA Region IV's guidance: Determination of The Mechanical Integrity of Injection Wells.

MPC will conduct external mechanical integrity testing (MIT) annually to meet the requirements of 40 CFR 146.90(e), as described below. The following MITs will be performed:

- **Pulsed-neutron capture (PNC) logging** will be deployed to quantify the flow of water in or around the borehole. Following a baseline PNC log prior to the start of CO_2 injection, subsequent runs will be compared to baseline conditions to determine changes in fluid flow adjacent to the well bore (i.e., formation of channels or other fluid isolation concerns related to the well).

- **Temperature logging** may detect fluid movement through perforations or any potential casing leaks.

MPC will run a PNC logging tool in each of the deep injection and monitoring wells. PNC and temperature logs will be run annually during the injection phase at the Kemper County Storage Complex, satisfying the annual MIT requirement. MPC will also deploy a PNC logging tool as a baseline measurement one year prior to the beginning of CO_2 injection. In the post-injection phase of the project, MPC will run the PNC and temperature logging tools every other year.

G.2. Testing details

Since the primary purpose of the external MIT is to demonstrate that there is no upward migration of fluid out of the storage zone, the PNC logging tool will be run to a depth greater than the base of caprock. Because the injection tubing will extend to a depth below the caprock, the PNC logs will be run inside the tubing; therefore, it will not be necessary to remove the injection tubing to conduct the PNC logging.

H. Pressure Fall-off Testing

MPC will perform pressure fall-off tests during the injection phase as described below to meet the requirements of 40 CFR 146.90(f).

H.1. Testing location and frequency

The minimum frequency at which MPC will perform pressure fall-off testing is as follows:

- Prior to injection (baseline)

- During injection, at least once every 3 years (transient testing requirement is once every 5 years according to 40 CFR 146.90 (f))

- At the end of the injection period and/or prior to well abandonment.

MPC will plan to schedule pressure fall-off tests during times of planned well maintenance (i.e., periodic well workovers), which is expected to occur more frequently than the minimum requirement (once every 5 years). As such, routing pressure monitoring would be conducted during periods when the injection wells are shut down.

Pressure fall-off tests will be conducted during periodic well workovers, or at a minimum once every three years, during injection to calculate the annual ambient average reservoir pressure. The pressure falloff tests will be conducted prior to the start of CO_2 injection, periodically during the injection phase, and prior to well abandonment. At a minimum, MPC will attempt all planned pressure fall-off tests to be preceded by one week of continuous CO_2 injection at relatively constant rate. The well will be shut-in for at least four days or longer until adequate pressure transient data are measured and recorded to calculate the average pressure. These data will be measured using a surface readout down-hole gauge so a real-time decision about test duration can be made after the data are analyzed for average pressure.

H.2. Testing details

A pressure fall-off test includes a period of injection followed by a period of non-injection or shut down. Normal injection using the stream of CO_2 captured from the MPC facility will be used during the injection period preceding the shut-in portion of the falloff tests. The average injection rate is estimated to be ~4,000 MT/day per well. Prior to the fall-off test this rate will be maintained. If this rate causes relatively large changes in bottomhole pressure, the rate may be decreased. Injection will have occurred for at least 2.5 years prior to this test, but there may have been injection interruptions due to operations or testing. At a minimum, one week of relatively continuous injection at a sustained rate will precede the shut-in portion of the fall-off test; however, several months of injection prior to the fall-off will likely be part of the pre-shut-in injection period and subsequent analysis. This data will be measured using a surface readout downhole gauge so a final decision about test duration can be made after the data is analyzed for average pressure. The gauges may be those used for day-to-day data acquisition, or a pressure gauge will be conveyed via wireline.

To reduce the wellbore storage effects attributable to the pipeline and surface equipment, the well will be shut-in at the wellhead nearly instantaneously with direct coordination with the injection compression facility operator. Because surface readout will be used and downhole recording memory restrictions will be eliminated, data will be collected at intervals of five seconds or less for the duration of test. The shut-in period of the fall-off test will be a minimum of four days, continuing until adequate pressure transient data are collected to calculate the average pressure. Because surface readout gauges will be used, the shut-in duration can be determined in real-time. A report containing the pressure fall-off data and interpretation of the reservoir ambient pressure will be submitted to the permitting agency within 90 days of the test. Pressure sensors used for this test will be the wellhead sensors and a downhole gauge for the pressure fall-off test. Each gauge will be of a type that meets or exceeds ASME B 40.1 Class 2A (0.5% accuracy across full range). Wellhead pressure gauge range will be 0-4,000 psi. Downhole gauge range will be 0-10,000 psi.

I. Carbon Dioxide (CO_2) Plume and Pressure Front Tracking

MPC will employ direct and indirect methods to track the extent of the CO_2 plume and the presence or absence of elevated pressure during the operation period to meet the requirements of 40 CFR 146.90(g).

Direct monitoring of pressure will be used to assess the lateral extent of injected CO_2 and the pressure front within the injection zone. In addition to surface methods, downhole geophysical methods and logging tools will be used to provide an indirect measure of CO_2 plume development and spatial distribution. This section describes the proposed injection zone monitoring program.

During the 30-year active injection phase, continuous (i.e., uninterrupted) monitoring of pressure will be conducted in the two above-zone and five in-zone monitoring wells in addition to the two CO_2 injection wells. The pressure gauges will be removed from the monitoring wells only when they require maintenance or when necessitated by other activities (e.g., well maintenance). In addition, each of the five in-zone and two above-zone monitoring wells will be sampled (i.e., fluid sampling) on an annual basis during injection operations to quantify CO_2 arrival times and transport processes. Baseline pressurized fluid samples will be collected prior to the start of injection operations. The two CO_2 injection wells will not be sampled during the operational phase so as not to interfere with injection operations. However, the CO_2 injection stream will be monitored/sampled during this phase and the injection wells will be sampled after the conclusion of the injection period. Aqueous samples will be analyzed for the same parameters (see groundwater and geochemistry monitoring above the confining zone in **Section F** of this plan) that are measured during the baseline monitoring period.

The primary objective of monitoring injection zone pressure is to provide data needed to adequately assess the lateral extent of injected CO_2 and the pressure front over time. Specific objectives for monitoring injection zone pressure include the following:

- Calibrate the numerical models that will be used to help track CO_2 and pressure in the injection zone.
- Guard against over-pressuring, which could induce unwanted fracturing of the injection zone or the overlying confining zone(s).
- Determine the need for well rehabilitation.
- Assess injection zone properties (e.g., permeability, porosity, reservoir size) within progressively larger areas of the reservoir as the pressure front advances.

Data collection will be accomplished by monitoring pressure within the six wells completed in the injection zone (four in-zone monitoring wells and two injection wells) in addition to the two above-zone monitoring wells. PNC logging (or RST logs) will occur annually during the injection phase, with the results related to CO_2 saturations providing additional data to further calibrate MPC's numerical models. Flow injection profile surveys will also be employed to evaluate how the injection stream is partitioned across the perforations at the injection wells. Temperature and electrical conductivity will be monitored at all well locations with a downhole, combined pressure/temperature/electrical conductivity sensor tool in conjunction with PNC logging activities.

I.1. Plume monitoring location and frequency

MPC will collect baseline, pressurized fluid samples from the injection interval (Paluxy Formation) at each of the two injection wells in accordance with 40 CFR 146.87 (b)(c). More information on the parameters to be analyzed as part of fluid sampling in the injection zone as well as the results from injection zone fluid sampling are provided in the *Pre-Operational Testing Plan*. **Table 8** below presents the methods that MPC will use to monitor the position of the CO_2 plume.

As discussed earlier in the overall strategy and ground water monitoring subsections of this plan, MPC determined that the geochemical risks associated with geochemical interactions of CO_2 and the injection zone are very low. This was confirmed by the Risk Assessment that is detailed in *Emergency and Remedial Response Plan*. Based on these findings, MPC will not collect fluid samples from either of the two injection wells during the injection phase and will halt fluid sampling from the in-zone monitoring wells once the CO_2 plume has reached and been confirmed in each monitoring well. Continued monitoring activities within wells where the plume has been confirmed could potentially exacerbate the risks of CO_2 migrating above the main confining zone into potential USDW aquifers by creating a potential pathway for CO_2 migration. Quality assurance procedures for these methods are presented in the *Quality Assurance Surveillance Plan.*

Table 8. Plume monitoring activities.

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
DIRECT PLUME MONITORING				
Upper Tuscaloosa Sand	Fluid Sampling (Above-Zone)	MPC 19-1	1 Point Location, 1 Interval. Approx. Depths: 2550-2552	Baseline; Annually over 30-year injection period
		MPC 20-2	1 Point Location, 1 Interval. Approx. Depths: 2550-2552	Baseline; Annually over 30-year injection period
Paluxy	Fluid Sampling (In-Zone)	MPC 19-2 (Injection Well)	1 Point Location, 1 Interval. Approx. Depths: 2550-2552	Baseline Pressurized Fluid Sample Only
		MPC 32-1 (Injection Well)	1 Point Location, 1 Interval. Approx. Depths: 2600-2602	Baseline Pressurized Fluid Sample Only
		MPC 26-5 (In-Zone Monitoring Well)	1 Point Location, 1 Interval. Approx. Depths: 2600-2602	Baseline; Annually During Injection until CO_2 Plume is observed.
		MPC 20-1 (In-Zone Monitoring Well)	1 Point Location, 1 Interval. Approx. Depths: 2550-2552	Baseline; Annually During Injection until CO_2 Plume is observed.
		MPC 34-1 (In-Zone Monitoring Well)	1 Point Location, 1 Interval. Approx. Depths: 2600-2602	Baseline; Annually During Injection until CO_2 Plume is observed.
		MPC 01-1 (In-Zone Monitoring Well)	1 Point Location, 1 Interval. Approx. Depths: 2550-2552	Baseline; Annually During Injection until CO_2 Plume is observed.
		MPC 10-4 (In-Zone Monitoring Well)	1 Point Location, 1 Interval. Approx. Depths: 2500-2502	Baseline; Annually During Injection until CO_2 Plume is observed.

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
INDIRECT PLUME MONITORING				
Upper Tuscaloosa Sand	PNC/RST Logs, Temperature Logs	MPC 19-1	1 Point Location & continuous to full well depth	Annually during injection operations.
		MPC 20-2	1 Point Location & continuous to full well depth	Annually during injection operations.
Paluxy	PNC/RST Logs, Temperature Logs	MPC 19-2 (Injection Well)	1 Point Location & continuous to full well depth	Annually during injection operations.
		MPC 32-1 (Injection Well)	1 Point Location & continuous to full well depth	Annually during injection operations.
		MPC 01-1 (In-Zone Monitoring Well)	1 Point Location & continuous to full well depth	Annually during injection operations.
		MPC 10-4 (In-Zone Monitoring Well)	1 Point Location & continuous to full well depth	Annually during injection operations.
		MPC 26-5 (In-Zone Monitoring Well)	1 Point Location & continuous to full well depth	Annually during injection operations.
		MPC 20-1 (In-Zone Monitoring Well)	1 Point Location & continuous to full well depth	Annually during injection operations.
		MPC 34-1 (In-Zone Monitoring Well)	1 Point Location & continuous to full well depth	Annually during injection operations.
Paluxy	Flow Profile Surveys	MPC 19-1 (Injection Well)	1 Point Location & continuous to full well depth	Annually during injection operations.
		MPC 32-1 (Injection Well)	1 Point Location & continuous to full well depth	Annually during injection operations.

I.2. Plume monitoring details

MPC will employ fluid sampling in the injection zone (Paluxy Formation) at each of the five in-zone monitoring wells to provide direct plume monitoring (see **Section C** earlier in this plan).

As discussed earlier in this plan, the locations of the five in-zone monitoring wells will enable MPC to directly monitor the movement and progression of the CO_2 plume via fluid sampling. MPC expects that MPC 20-1 well will first encounter and observe CO_2 plume given its proximity to the two CO_2 injection wells and it's position relative to the observed formation dip across the Kemper County Storage Complex AoR. The spatial distribution of the monitoring well network will allow MPC to track and confirm the CO_2 plume over the course of the 30-year injection period. Once the CO_2 plume is observed and confirmed in each of the five in-zone monitoring wells, annual fluid sampling will be discontinued to mitigate potential risks associated with CO_2 migration through the primary confining zone. MPC will continue to monitor and collect pressure data (continuous) and annual PNC and temperature logs after CO_2 plume has been detected and fluid sampling has stopped in the five in-zone monitoring wells. During this process, MPC will seek to compare AoR model behavior with monitoring data and assess if a re-evaluation is required prior to a five-year interval.

The parameters to be analyzed as part of fluid sampling in the injection zone and associated analytical methods are presented in **Table 9**.

Table 9: Summary of Analytical and Field Parameters for Fluid Sampling in the Paluxy Formation.

Parameters	Analytical Methods
Paluxy (Injection Interval)	
Cations: Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb, Se, and Tl	ICP-MS, EPA Method 6020
Cations: Ca, Fe, K, Mg, Na, and Si	ICP-OES, EPA Method 6010B
Anions: Br, Cl, F, NO_3 and SO_4	Ion Chromatography, EPA Method 300.0
Dissolved **CO_2**	Coulometric titration, ASTM D513-11
Isotopes: S13C of DIC	Isotope ratio mass spectrometry
Total Dissolved Solids	Gravimetry, APHA 2540C
Water Density	Oscillating body method
Alkalinity	APHA 2320B
pH (field)	EPA 150.1
Specific conductance (field)	APHA 2510
Temperature (field)	Thermocouple

Indirect plume monitoring will be conducted using pulsed neutron capture (PNC) logs and RST logs to monitor CO_2 saturations and to track the movement of the expected CO_2 plume. Based on the compositional reservoir modeling results, the spatial distribution of the four in-zone monitoring wells based on this project's overall monitoring network design and strategy will enable MPC to confirm the extent of the CO_2 plume migration over the course of the 30-year injection period. **Figure 2** shown earlier in this plan illustrates the in-zone monitoring locations relative to the predicted location of the CO_2 plume and pressure front.

MPC will conduct annual PNC logs for the nine deep wells, including the two injection wells and seven deep monitoring wells, during the injection phase. Once CO_2 injection has ceased, MPC will run logs every other year during the post-injection phase of the project. Additionally, PNC logs will be run prior to CO_2 injection (baseline) as well as before the plugging of any well during the post-injection site care phase of the project.

MPC will also employ a temperature log that will be deployed and collected in conjunction with each PNC logging run. The information from these logging activities will provide ample data sets to calibrate the geologic models incorporated within the numerical models to the field performance data.

I.3. Pressure-front monitoring location and frequency

Table 10 presents the methods that will be used to monitor the position of the pressure front, including the activities, locations, and frequencies MPC will employ.

Baseline pressure monitoring will involve the installation and testing of pressure sensors in the injection well and monitoring wells and collection of pressure data for approximately 1 year prior to the start of injection. Thus, baseline injection zone pressure monitoring cannot be initiated until the wells have been installed.

During the 30-year active injection phase, continuous monitoring of pressure will be conducted in the five in-zone monitoring wells, two CO_2 injection wells, and two above-zone monitoring wells. The pressure gauges will be removed from the monitoring wells only when necessary, such as during maintenance. Injection wells will not be sampled during the operational phase so as not to interfere with injection operations. However, the CO_2 injection stream will be monitored and sampled during this phase. Monitoring data will be continuously evaluated throughout the active injection phase and if specific analytes are found to be of little benefit, they will be removed from the analysis list.

Post-injection monitoring data will continue to be collected and evaluated to determine when the injected CO_2 can no longer affect the USDW aquifers. This demonstration requires knowledge of pressure data for the injection reservoir; therefore, pressure monitoring in wells in the injection reservoir will continue throughout the post-injection monitoring period. At least three of the four monitoring wells in the injection zone will be retained for this purpose. Monitoring of the injection zone fluids is not required during this phase of the project, but periodic samples may be collected to characterize longer-term geochemical changes occurring within the injection zone. Aqueous monitoring of injection zone fluids during this phase, if performed, will be conducted at a reduced frequency (i.e., every 5 years).

With regards to indirect plume and pressure monitoring activities, MPC will conduct cased-hole Pulsed Neutron Capture (PNC) and temperature logging as well as injection flow profile surveys on an annual basis during the injection period.

Quality assurance procedures for these methods are presented in the *Quality Assurance and Surveillance Plan*.

I.4. Pressure-front monitoring details

Injection of CO_2 into a saline aquifer generates pressure perturbations that diffuse through the fluid-filled pores of the geologic system. The objective of pressure monitoring is to record the pressure signal at the source (i.e., injection well) and one or more monitoring wells in order to infer important rock and fluid characteristics such as permeability and total compressibility from the analysis of the pressure data. Pressure monitoring information also provides input for the calibration of numerical models, where injection zone properties are adjusted to match the observed pressure data with corresponding simulation predictions. This provides confirmation of predictions regarding the extent of the CO_2 plume, pressure buildup, and the occurrence of fluid displacement into overlying formations.

Pressure in the injection zone will be monitored at several well locations (see the conceptual monitoring network design shown in **Figure 2**), including the two injection wells, five in-zone monitoring wells, and two above-zone monitoring wells in the Upper Tuscaloosa Sand located within the projected 20-year post-injection CO_2 plume extent.

Pressure monitoring as a component of the overall MVA program provides multiple benefits. Inferences about formation permeability at scales comparable to that of CO_2 plume migration can be made (as opposed to that from small centimeter-scale core samples). Permeability values estimated for different regions of the injection zone may indicate the presence of anisotropy and hence, suggest potential asymmetry in the plume trajectory. Such information can be useful in adapting the monitoring strategy.

Continuous monitoring of injection zone pressure will be performed with sensors installed in wells that are completed in the injection zone. Pressure monitoring in the injection well and all monitoring wells will be performed using a real-time monitoring system with surface readout capabilities so that pressure gauges do not have to be removed from the well to retrieve data. The following measures will be taken to ensure that the pressure gauges are providing accurate information on an ongoing basis:

- High-quality (high-accuracy, high-resolution) gauges with low drift characteristics will be used.
- Gauge components (gauge, cable head, cable) will be manufactured of materials designed to provide a long-life expectancy for the anticipated downhole conditions.
- Upon acquisition, a calibration certificate will be obtained for every pressure gauge. The calibration certificate will provide the manufacturer's specifications for range, accuracy (% full scale), resolution (% full scale), drift (< psi per year) and calibration results for each parameter. The calibration certificate will also provide the date that the gauge was calibrated, and the methods and standards used.
- Gauges will be installed above any packers so they can be removed if necessary for recalibration by removing the tubing string. Redundant gauges may be run on the same cable to provide confirmation of downhole pressure and temperature.
- Upon installation, all gauges will be tested to verify they are functioning (reading/transmitting) correctly.
- Gauges will be pulled and recalibrated each time a workover occurs that involves removal of tubing. A new calibration certificate will be obtained each time a gauge is re-calibrated.

MPC will conduct annual PNC logs for the nine deep wells, including the two injection wells and seven deep monitoring wells, during injection. Once CO_2 injection has ceased, MPC will run PNC logs every other year during the post-injection phase of the project. Additionally, PNC logs will be run prior to beginning CO_2 injection to establish a baseline as well as before the plugging of any well during the post-injection site care phase of the project.

MPC will conduct annual injection flow profile surveys at each of the two injection wells to understand how the injection stream is partitioned across the perforations. This will provide ample data sets to calibrate the geologic models incorporated within the numerical models to the field performance data.

Table 10: Pressure-front monitoring activities, location, spatial coverage, and frequency.

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
DIRECT PRESSURE-FRONT MONITORING				
Upper Tuscaloosa Sand	Pressure Monitoring	MPC 19-1 (Above-Zone)	1 Point Location, 1 Interval. Approx. Depths: 2550-2552	Continuous
		MPC 20-2 (Above-Zone)	1 Point Location, 1 Interval. Approx. Depths: 2550-2552	Continuous
Paluxy	Pressure Monitoring	MPC 19-2 (Injection)	1 Point Location, 1 Interval. Approx. Depths: 2550-2552	Continuous
		MPC 32-1 (Injection)	1 Point Location, 1 Interval. Approx. Depths: 2600-2602	Continuous
		MPC 26-5 (In-Zone Monit.)	1 Point Location, 1 Interval. Approx. Depths: 2600-2602	Continuous
		MPC 20-1 (In-Zone Monit.)	1 Point Location, 1 Interval. Approx. Depths: 2550-2552	Continuous
		MPC 34-1 (In-Zone Monit.)	1 Point Location, 1 Interval. Approx. Depths: 2600-2602	Continuous
		MPC 01-1 (In-Zone Monit.)	1 Point Location, 1 Interval. Approx. Depths: 2550-2552	Continuous
		MPC 10-4 (In-Zone Monit.)	1 Point Location, 1 Interval. Approx. Depths: 2500-2502	Continuous

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
INDIRECT PRESSURE-FRONT MONITORING				
Upper Tuscaloosa Sand	PNC/RST Logs and Temperature Logs	MPC 19-1 (Above-Zone)	1 Point Location & continuous to full well depth	Annually during injection
		MPC 20-2 (Above-Zone)	1 Point Location & continuous to full well depth	Annually during injection
Paluxy	PNC/RST Logs and Temperature Logs	MPC 19-1 (Injection)	1 Point Location & continuous to full well depth	Annually during injection
		MPC 32-1 (Injection)	1 Point Location & continuous to full well depth	Annually during injection
		MPC 01-1 (In-Zone Monit.)	1 Point Location & continuous to full well depth	Annually during injection
		MPC 10-4 (In-Zone Monit.)	1 Point Location & continuous to full well depth	Annually during injection
		MPC 26-5 (In-Zone Monit.)	1 Point Location & continuous to full well depth	Annually during injection
		MPC 20-1 (In-Zone Monit.)	1 Point Location & continuous to full well depth	Annually during injection
		MPC 34-1 (In-Zone Monit.)	1 Point Location & continuous to full well depth	Annually during injection
Paluxy	Flow Profile Surveys	MPC 19-1 (Injection)	1 Point Location & continuous to full well depth	Annually during injection
		MPC 32-1 (Injection)	1 Point Location & continuous to full well depth	Annually during injection

J. Seismicity and Fault Monitoring

Four previously reprocessed 2-D seismic lines were acquired from Seismic Exchange and were evaluated by the Geological Survey of Alabama using IHS Markit Kingdom 2d/3dPAK software and interpreted using the latest geophysical, stratigraphic, and structural techniques. The objectives of the seismic analysis were:

- to demonstrate the areal extent and continuity of prospective CO_2 storage reservoir sands,
- to show the lateral continuity of regional confining units above the prospective storage reservoirs, and
- to identify any cross-cutting faults.

The seismic interpretations confirmed that no known structural features (i.e., faulting) disrupt the storage complex geology (see *Application Narrative* for more information on these seismic interpretations and results).

Given the regional geologic setting described above, the depth of the targeted injection interval (Paluxy at approximately ~5,000 ft depth), and the lack of any known preferential pathways between the injection zone interval and USDW aquifers, the likelihood of CO_2 coming into direct contact with the lowermost USDW aquifer (Upper Cretaceous Eutaw formation) and the associated impacts on water quality is considered to be very low at the Kemper County Storage Complex.

K. Surface Air and Soil Gas Monitoring

The need for surface-monitoring approaches will be continually evaluated throughout the operational phase of the project and could be incorporated into the MVA assessment if circumstances warrant. Given MPC's current conceptual understanding of the subsurface environment, there is a very low risk of contaminating ground water drinking sources and minimal chance of surface disruption is anticipated by completing multiple monitoring wells on a single well pad, where applicable. As such, extensive networks of surface-water, soil-gas, and atmospheric monitoring stations are not warranted at this time. Any implemented surface-monitoring networks would be optimized to provide good areal coverage, while also focusing on areas of higher leak potential (e.g., near the injection wells or other abandoned well locations).

Kemper County Storage Complex

Proposed Injection Well 19-2

Mississippi Power Company

Quality Assurance and Surveillance Plan

40 CFR 146.90 (k)

Facility Information

Facility name:	Kemper County Storage Complex
	Well Name: MPC 19-2
Facility contact:	Mississippi Power Company
	Environmental Affairs
	P.O. Box 4079
	Gulfport, MS 39502-4079
Well location:	Kemper County, Mississippi
	Latitude: 32.6130560; Longitude: -88.8061110

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Title and Approval Sheet

This Quality Assurance and Surveillance Plan (QASP) is approved for use and implementation at Plant Ratcliffe, operated by the Mississippi Power Company (MPC). The signatures below denote the approval of this document and intent to abide by the procedures outlined within it.

Signature	Date
Printed Name	
Title	

Signature	Date
Printed Name	
Title	

Signature	Date
Printed Name	
Title	

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List of Acronyms/Abbreviations

AoR	Area of Review
CCUS	Carbon capture, utilization, and storage
CO_2	Carbon dioxide
CMG	Computer Modelling Group
DOE	Department of Energy
ECO_2S	Establishing An Early Carbon Dioxide Storage
EPA	Environmental Protection Agency
ERRP	Emergency and Remedial Response
ft	feet
mg/L	milligrams per liter
MMt	Millions of Metric tons
MPC	Mississippi Power Company
PISC	Post-Injection Site Care
psi	Pounds per square inch
RCA	Routine Core Analysis
SS	Sub- Sea
TVD	True Vertical Depth
UIC	Underground Injection Control
USDW	Underground Source of Drinking Water

A. Project Management

A.1 Project/Task Organization

A.1.a/b Key Individuals and Responsibilities

The project, led by Mississippi Power Company (MPC), includes participation from several subcontractors. The Testing and Monitoring activities and related responsibilities will be shared between MPC and their selected subcontractors. Tasks which are related to testing and monitoring that will require supervision for purposes of quality control and assurance are broadly divided into:

1. Groundwater Sampling and Analysis
2. Well Logging
3. Mechanical Integrity Testing
4. Injection Monitoring
5. CO_2 Stream Sampling and Analysis
6. Geophysical Monitoring

A.1.c Independence from Project Quality Assurance (QA) Manager and Data Gathering

Physical samples collected and other data gathered as part of the monitoring, verification, and accounting (MVA) program will be analyzed, processed, or witnessed by third parties independent and outside of the project management structure. A final list of vendors, subcontractors, and independent testing labs with access to the monitoring data generated through this project will be provided by MPC.

A.1.d QA Project Plan Responsibility

MPC will be responsible for maintaining and distributing the official, approved Quality Assurance Surveillance Plan (QASP). MPC will periodically review this QASP and consult with U.S. EPA if/when changes are warranted.

A.2 Problem Definition/Background

A.2.a Reasoning

MPC's MVA program has operational monitoring, verification, and environmental monitoring components. Operational monitoring is used to ensure safety with all procedures associated with fluid injection, monitoring the response of the injection interval at the wellsite, and the movement of the CO_2 plume and pressure front. Key monitoring parameters include: injection well tubing and annulus pressures and the injection zone reservoir pressure and fluid chemistry, which will be monitored by in-zone and above-zone monitoring wells. Other monitoring parameters include injection rate, total mass of CO_2 injected, injection well temperature profile, and fluid sampling. Fluid samples will be collected pre- and post-injection from the injection interval (Paluxy Formation), Above-zone (Upper Tuscaloosa Sand that overlies the primary confining zone), deep USDW (Eutaw), and shallow groundwater (Wilcox) through monitoring wells. The verification component will provide information to evaluate if leakage of CO_2 through the caprock occurs as well as provide data for modeling and verification of CO_2 plume migration. This verification process will be accomplished through the use of Pulse Neutron Capture logging (PNC), pressure and temperature monitoring in the Paluxy Formation and the Upper Tuscaloosa Sand, well profile surveys, and reservoir saturation tool logging.

The knowledge and experience gained through the Carbon Safe Project ECO_2S Phases II and III provide a high level of confidence that the storage interval, identified as the Paluxy Formation, is capable of acceptting and permanently retaining the injected CO_2. The primary goal of the Kemper County Storage Complex program is to demonstrate that project activities are protective of human health and the environment. This QASP was developed to ensure that the quality standards of the testing and monitoring program meet the requirements of the U.S. EPA Underground Injection Control (UIC) Program for Class VI wells.

A.2.b Reasons for Initiating the Project

Southern Company has previously announced the goal significantly reducing their carbon emissions from their power-generation fleet. The implementation of carbon capture and geologic storage is a major component of their proposed plan. As such, the primary objective of of the Kemper County Storage Complex project is to permanently store CO_2 emissions within the Paluxy Formation. In order to demonstrate that this can be done safely and at commercial scale, a rigorous project plan is proposed to ensure that injected CO_2 is retained within the intended storage reservoir.

A.2.c Regulatory Information, Applicable Criteria, Action Limits

The Class VI Rule requires owners or operators of Class VI wells to perform several types of activities during the lifetime of the project in order to ensure that the injection well maintains its mechanical integrity, that fluid migration and the extent of pressure elevation are within the limits described in the permit application, and that USDWs are not endangered. These monitoring activities include mechanical integrity tests (MITs), injection well testing during operation, monitoring of ground water quality, and tracking of the CO_2 plume and associated pressure front. This document details both the measurements that will be taken as well as the steps to ensure that the quality of all the data is such that the data can be used with confidence in making decisions during the life of the project.

A.3 Project/Task Description.

A.3.a/b Summary of Work to be Performed

Table 1 describes the Testing and Monitoring tasks, reasoning, and location. Summarized in **Table 2** are the instrumentation and geophysical surveys, respectively.

Table 1: Summary of Testing and Monitoring

Activity	Location(s)	Method	Analytical Technique	Purpose
Carbon dioxide stream analysis	Compressor; post-dehydration	Direct Sampling	Chemical Analysis	Monitor Injectate
Groundwater quality	Shallow observation wells, above-zone wells	Shallow groundwater sampling (ASTM-D4448) and Kuster Flow Sampler (deep)	Chemical Analysis	Groundwater monitoring
Injection Rate and Volume	At surface wellheads	Flow Meter	Continuous Direct Measurement	Continuous monitoring of injection rate and volume
Injection Pressure	MPC 19-2 Wellhead	Wellhead pressure and temperature gauge	Continuous Direct Measurement	Continuous monitoring of injection pressure
Annular Pressure	MPC 19-2 Wellhead	Annular Pressure Gauge	Continue Direct Measurement	Continuous monitoring of annulus pressure
Annular Volume	Surface Annular Pressure Vessel	Annular Volume Gauge	Continuous Direct Measrement	Continuous monitoring of annulus
Downhole pressure/ temperature	MPC 19-2: Paluxy Formation	Downhole Gauges	Direct Measurement	Continuous monitoring of injection zone pressure and temperature
Corrosion monitoring	Post-compression and Dehydration	Corrosion Coupons	Chemical Analysis	Continuous monitoring of injectate and casing inspection
Mechanical integrity	MPC 19-2	Internal – Annular pressure gauge monitoring	Direct Measurement	Demonstration of internal and external mechanical integrity of the wellbore
		External – Distributed Temperature Sensing (DTS)	Distributed Indirect Measurement	
Pressure fall-off testing	MPC 19-2	Pressure Gauge	Direct Measurement	Pressure fall-off testing
CO_2 Plume Monitoring	MPC 19-2: Paluxy Formation	Downhole Pressure and Temperature Gauges	Direct Measurement	Monitoring of plume migration and pressure tracking
	AoR, All injection in-zone and above zone monitoring wells	Pulsed Neutron Capture (PNC) logs	Indirect measurement and mapping	
Leak detection/inspection	Surface wellhead, piping and valves for all wells	Valve inspection and testing, flow meter accounting	Direct measurement	Leak detection

Table 2: Instrumentation Summary

Monitoring Location	Instrument Type	Monitoring Target (Formation or Other)	Data Collection Location(s)	Frequency
MPC 19-2 (Injection)	Pressure	Paluxy (In-Zone)	1 Point Location, 1 Interval. Approx. Depths: 5050	Continuous
	Temperature, PNC/RST logs	Paluxy (In-Zone)	1 Point Location & continuous to full well depth	Annually during injection
	Flow	Paluxy (In-Zone)	1 Point Location & continuous to full well depth	Annually during injection
MPC 32-1 (Injection)	Pressure	Paluxy (In-Zone)	1 Point Location, 1 Interval. Approx. Depths: 5050	Continuous
	Temperature, PNC/RST logs	Paluxy (In-Zone)	1 Point Location & continuous to full well depth	Annually during injection
MPC 19-1	Pressure	Upper Tuscaloosa Sand (Above-Zone)	1 Point Location, 1 Interval. Approx. Depths: 3300	Continuous
	Temperature, PNC/RST logs	Upper Tuscaloosa Sand (Above-Zone)	1 Point Location & continuous to full well depth	Annually during injection
MPC 20-2	Pressure	Upper Tuscaloosa Sand (Above-Zone)	1 Point Location, 1 Interval. Approx. Depths: 3200	Continuous
	Temperature, PNC/RST logs	Upper Tuscaloosa Sand (Above-Zone)	1 Point Location & continuous to full well depth	Annually during injection
MPC 26-5	Pressure	Paluxy (In-Zone)	1 Point Location, 1 Interval. Approx. Depths: 5100	Continuous
	Temperature, PNC/RST logs	Paluxy (In-Zone)	1 Point Location & continuous to full well depth	Annually during injection
MPC 20-1	Pressure	Paluxy (In-Zone)	1 Point Location, 1 Interval. Approx. Depths: 5050	Continuous
	Temperature, PNC/RST logs	Paluxy (In-Zone)	1 Point Location & continuous to full well depth	Annually during injection
MPC 34-1	Pressure	Paluxy (In-Zone)	1 Point Location, 1 Interval. Approx. Depths: 4950	Continuous
	Temperature, PNC/RST logs	Paluxy (In-Zone)	1 Point Location & continuous to full well depth	Annually during injection
MPC 01-1	Pressure	Paluxy (In-Zone)	1 Point Location, 1 Interval. Approx. Depths: 5050	Continuous
	Temperature, PNC/RST logs	Paluxy (In-Zone)	1 Point Location & continuous to full well depth	Annually during injection
MPC 10-4	Pressure	Paluxy (In-Zone)	1 Point Location, 1 Interval. Approx. Depths: 4750	Continuous
	Temperature, PNC/RST logs	Paluxy (In-Zone)	1 Point Location & continuous to full well depth	Annually during injection

A.3.c Geographic Locations

Figure 1 shows the Kemper County Storage Complex site and monitoring infrastructure. Note that the proposed monitoring wells are arranged on seven different pads that surround the proposed AoR, demarked below by the CO_2 plume 20 years after injection. The planned In-zone and Above-zone wells are given the MPC label, while the Shallow Monitoring Wells and Deep Monitoring Wells are labeled as SH and DP, respectively.

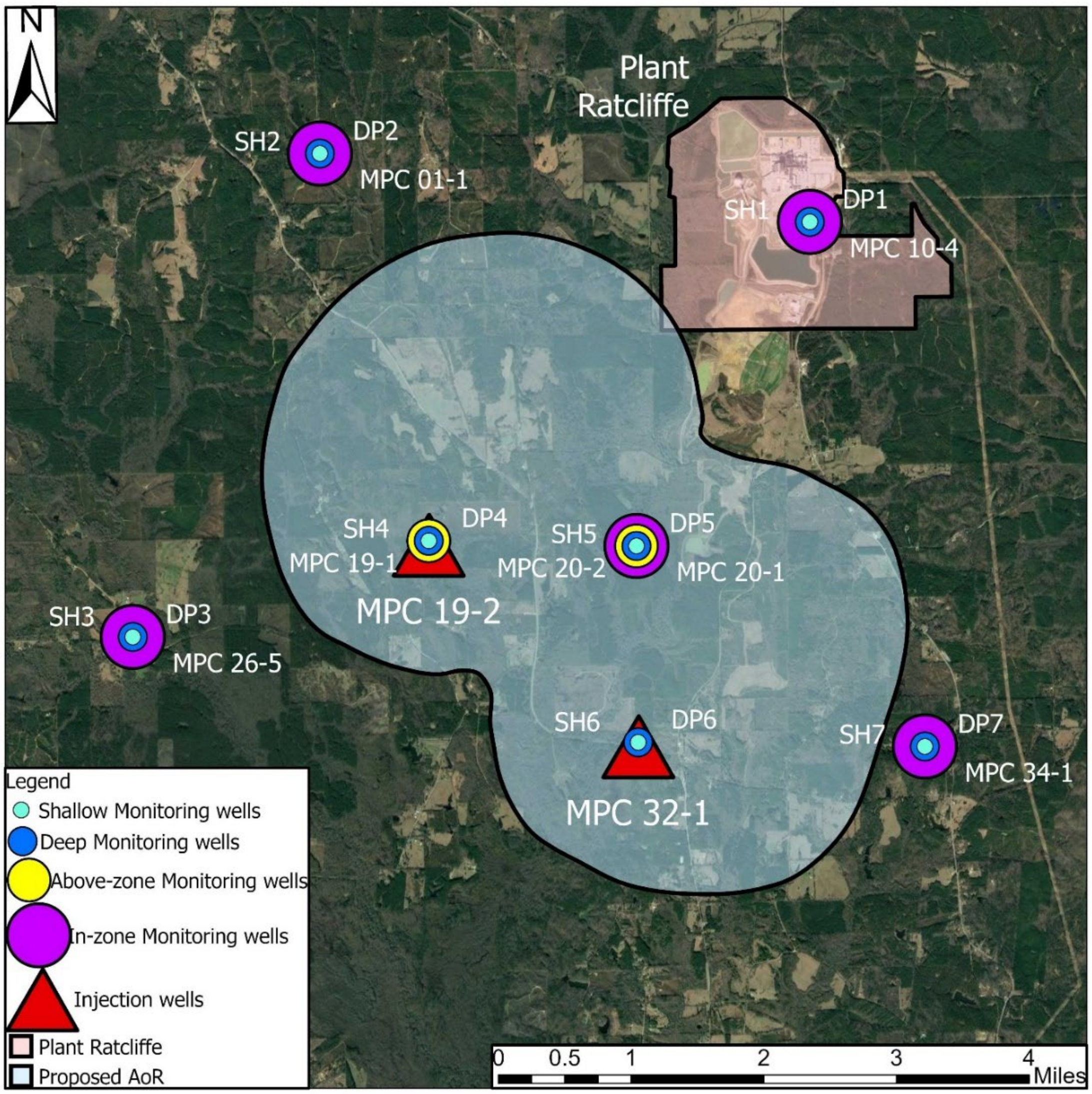

Figure 1: Regional view of project study area showing the proposed locations of the injection wells, monitoring wells, and the proposed AoR.

A.4 Quality Objectives and Criteria

A.4.a Performance/Measurement Criteria

The overall objective for testing and monitoring is to develop and implement procedures for subsurface monitoring, field sampling, laboratory analysis, and reporting which will provide results to meet the characterization and non-endangerment goals of this project. Groundwater monitoring will be conducted during the pre-injection, injection, and post-injection phases of the project. Shallow and deep groundwater monitoring wells will be used to gather waterquality samples and pressure data. All groundwater analytical and field monitoring parameters for each interval are listed in **Table 3**. Analytical parameters for CO_2 stream gas monitoring, corrosion coupon assessment, and gauge specifications are shown in **Table 4** through **Table 7.** **Table 8** shows the actionable testing and monitoring outputs. The list of analytes may be reassessed periodically and adjusted to include or exclude parameters based on their effectiveness to the overall monitoring program goals. Key testing and monitoring areas include:

1. Shallow Groundwater Sampling
   a. Aqueous chemical concentrations
2. Deep Formation Fluid Sampling
   a. Aqueous chemical concentrations
3. Well Logging
   a. Pulsed neutron logs
4. Mechanical Integrity Testing (MIT)
   a. Pulsed neutron logs
   b. Ttemperature logs
   c. Cement bond logging
5. Pressure/Temperature Monitoring
   a. Pressure/temperature from downhole gauges
   b. Pressure/temperature from surface gauges

6. CO_2 Stream Analysis
    a. CO_2 Purity (% v/v, [GC])
    b. Oxygen (O_2, ppm v/v)
    c. Nitrogen (N_2, ppm v/v)
    d. Carbon Monoxide (CO, ppm v/v)
    e. Oxides of Nitrogen (NO_x, ppm v/v)
    f. Total Hydrocarbons (THC, ppm v/v as CH_4)
    g. Methane (CH_4, ppm v/v)
    h. Acetaldehyde (AA, ppm v/v)
    i. Sulfur Dioxide (SO_2, ppm v/v)
    j. Hydrogen Sulfide (H_2S ppm v/v)
    k. Ethanol (ppm v/v)

Table 3: Summary of Analytical and Field Parameters for Shallow and Deep Above-Zone Fluid Sampling

Parameters	Analytical Methods[1]	Detection Limit/Range	Typical Precisions	QC Requirements
Cations: Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb, Se, and Tl	ICP-MS EPA Method 6020	0.001 to 0.1 mg/L (analyte, dilution and matrix dependent)	±15%	Daily Calibration; blanks, duplicates and matrix spikes at 10% or greater frequency
Cations: Ca, Fe, K, Mg, Na, and Si	ICP-OES EPA Method 6010B	0.005 to 0.5 mg/L (Analyte, dilution and matrix dependent)	±15%	Daily Calibration; blanks, duplicates and matrix spikes at 10% or greater frequency
Anions: Br, Cl, NO_3, and SO_4	Ion Chromatography EPA Method 300.0	0.02 to 0.13 mg/L (analyte, dilution and matrix dependent)	±15%	Daily Calibration: blanks and duplicates at 10% or greater frequency
Dissolved CO_2	Coulometric Titration ASTM 513-11	25 mg/L	±15%	Duplicate measurement; standards at 10% or greater frequency
Total Dissolved Solids	Gravimetry APHA 2540C	12 mg/L	±15%	Balance calibration, duplicate analysis
Alkalinity	APHA 2320B	4 mg/L	±3 mg/L	Duplicate Analysis
pH (field)	EPA 150.1	2 to 12 pH units	±0.2 pH unit	User Calibration per manufacturer recommendation
Specific Conductance (field)	APHA 2510	0 to 200 mS/cm	±1% of reading	User calibration per manufacturer recommendation
Temperature (field)	Thermocouple	-5 to 50ºC	±0.2ºC	Factory Calibration

Abbreviations: ICP=inductively coupled plasma; MS= mass spectrometry; OES= Optical emission spectrometry; GC-P=Gas chromatography-Pyrolysis

Note 1: An equivalent method may be employed with the prior approval of the UIC Program Director.

Table 4: Summary of Analytical Parameters for CO_2 Stream

Parameters	Analytical Methods[1]	Detection Limit/Range	Typical Precisions	QC Requirements
Oxygen	ISBT 4.0 (GC/DID) GC/TCD	1 uL/L to 5,000 uL/L (ppm by volume)	± 10 % of reading	daily standard within 10 % of calibration, secondary standard after calibration
Nitrogen	ISBT 4.0 (GC/DID) GC/TCD	1 uL/L to 5,000 uL/L (ppm by volume)	± 10 % of reading	daily standard within 10 % of calibration, secondary standard after calibration
Carbon monoxide	ISBT 5.0 Colorimetric ISBT 4.0 (GC/DID)	5 uL/L to 100 uL/L (ppm by volume)	± 20 % of reading	duplicate analysis
Oxides of nitrogen	ISBT 5.0 Colorimetric	0.2 uL/L to 5 uL/L (ppm by volume)	± 20 % of reading	duplicate analysis
Total hydrocarbons	ISBT 10.0 THA (FID)	1 uL/L to 10,000 uL/L (ppm by volume)	5 - 10 % of reading relative across the range	daily blank, daily standard within 10 % of calibration, secondary standard after calibration
Methane	ISBT 10.1 GC/FID)	0.1 uL/L to 1,000 uL/L (ppm by volume)-dilution dependent	5 - 10 % of reading relative across the range	daily blank, daily standard within 10 % of calibration, secondary standard after calibration
Acetaldehyde	ISBT 11.0 (GC/FID)	0.1 uL/L to 100 uL/L (ppm by volume)- dilution dependent	5 - 10 % of reading relative across the range	daily blank, daily standard within 10 % of calibration, secondary standard after calibration
Sulfur dioxide	ISBT 14.0 (GC/SCD)	0.01 uL/L to 50 uL/L (ppm by volume)- dilution dependent	5 - 10 % of reading relative across the range	daily blank, daily standard within 10 % of calibration, secondary standard after calibration
Hydrogen sulfide	ISBT 14.0 (GC/SCD)	0.01 uL/L to 50 uL/L (ppm by volume)- dilution dependent	5 - 10 % of reading relative across the range	daily blank, daily standard within 10 % of calibration, secondary standard after calibration
Ethane	ISBT 10.1 (GC/FID)	0.1 uL/L to 100 uL/L (ppm by volume)- dilution dependent	5 - 10 % of reading relative across the range	daily blank, daily standard within 10 % of calibration, secondary standard after calibration
CO_2 purity	ISBT 2.0 Caustic absorption Zahm-Nagel	99.00% to 99.99%	± 10 % of reading	User calibration per manufacturer

Note 1: An equivalent method may be employed with the prior approval of the UIC Program Director.

Table 5: Specifications for MIT Testing and Monitoring Technologies

Logging Tool	Analytical Methods	Detection Limit/Range	Typical Precisions	QC Requirements	Calibration Frequency
Ultrasonic Cement Bong Log (SLB USI Tool)	Vendor best practice	0-10 MRayl	±0.5 MRayl	Vendor Calibration (3rd party)	Per Vendor Descretion
Pulse Neutron Capture Logging (SLB Pulsar and RST Tool)	Vendor best practice	Porosity: 0 to 60 pu	TBD	Vendor Calibration (3rd party)	Per Vendor Descretion
Distributed Temperature Sensing	Vendor best practice	-40ºF to 149ºF	0.01ºC	Vendor Calibration (3rd party)	Per Vendor Descretion

Table 6: Summary of Analytical Parameters for Corrosion Coupons

Parameters	Analytical Methods	Detection Limit/Range	Typical Precisions	QC Requirements
Mass	NACE RP0775-2005	.005mg	+/-2%	Annual Calibration of Scale (3rd Party Aldinger Co. – Cert #664896F)
Thickness	NACE RP0775-2005	.001mm	.001mm +/-005mm	Factory calibration

Table 7: Summary of Measurement Parameters for Field Gauges

Parameters	Methods	Detection Limit/Range	Typical Precisions	QC Requirements	Calibration Frequency
Booster pump discharge pressure	ANSI Z540-1-1994	+/- 0.001 psi / 0-3000 psi	+/- 0.01 psi	Annual Calibration of Scale (3rd party)	As suggested by manufacturer
Operational Annular Pressure Monitoring	ANSI Z540-1-1994	+/- 0.001 psi / 0-3000 psi	+/- 0.01 psi	Annual Calibration of Scale (3rd party)	As suggested by control system/gauge manufacturer
Wellhead Injection pressure (*PPS PPS31 Wellhead Pressure Logger or similar product*)	ANSI Z540-1-1994	0-15,000 psi	±0.03% FS	Annual Calibration of Scale (3rd party)	As suggested by gauge manufacterer
Injection mass flow rate (Emerson Coriolis mass flow meter)	*Unknown*	547.95-3561.64 tonnes(metric)/day	±0.1 of rate	Annual Calibration of Scale (3rd party)	As suggested by gauge manufacterer

Table 8: Actionable Testing and Monitoring Outputs

Activity or Parameter	Project Action Limit	Detection Limit	Anticipated Reading
MIT-DTS	Action to be taken when an temperature anomaly is observed	Refer to Table 5 for detection limits	Profiles observed during baseline
MIT-PNC Logging	Action to be taken when a CO_2 saturation anomaly is observed	Refer to Table 5 for detection limits	Brine saturated ~ 60 CO_2 saturated ~ 8
MIT- Annular Pressure Monitoring	<3% pressure loss over 1 hour	Refer to Table 5	>3% pressure loss over 1 hour
Surface/downhole pressure	Reservoir pressure >80% fracture gradient	refer to Table 3	Profiles TBD during baseline
Above-zone Water quality (fluid sampling)	Action to be taken when chemical profile anomaly is observed	refer to Table 3 for analyte detection limits	Profiles TBD during baseline
Above-confining-zone pressure	Action will be take when a pressure/temperature anomaly occurs	refer to Table 3	Profiles TBD during baseline

A.4.b Precision

For groundwater sampling, data accuracy will be assessed by the collection and analysis of field blanks to test sampling procedures and matrix spikes to test lab procedures. Field blanks will be taken no less than one per sampling event to spot check for sample bottle contamination. Laboratory assessment of analytical precision will be the responsibility of the individual laboratories per their standard operating procedures. **Table 9** summarizes the representative logging tool specifications.

Table 9: Representative Logging Tool Specifications

Parameter	USI	RST	DAS	DTS	Pulsar
Logging speed	1,800 ft/hr	150 ft/hr	NA	NA	1,000 ft/hr
Vertical resolution	6 inches	24 inches	*25cm	*25-50 cm	15 inches
Investigation	Casing-to-cement interface	4-6 inches	*0-24.8 miles	At fiber location	10-16 inches
Temperature rating	350°F (175°C)	300°F (150°C)	500°F	149ºF	350°F (175°C)
Pressure rating	20,000 psi	15,000 psi	20,000 psi	20 psi	15,000 psi

A.4.c Bias

Laboratory assessment of analytical bias will be the responsibility of the individual laboratories per their standard operating procedures and analytical methodologies. For direct pressure or logging measurements, there is no bias.

A.4.d Representativeness

For groundwater sampling, data representations express the degree to which data accurately and precisely constitute a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. The sampling network has been designed to provide data representative of site conditions. For analytical results of individual groundwater samples, representativeness will be estimated by ion and mass balances. Ion balances within ±10% error or less will be considered valid. Mass balance assessment will be used in cases where the ion balance is greater than ±10% to help determine the source of error. For a sample and its duplicate, if the relative percent difference is greater than 10%, the sample may be considered non-representative.

A.4.e Completeness

Data completeness in groundwater sampling is defined as a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under normal conditions. For the purposes of this project it is anticipated that data completeness of 90% for groundwater sampling will be acceptable to meet monitoring goals. In cases of direct pressure and temperature measurements, it is expected that data will be recorded no less than 90% of the time.

A.4.f Comparability

Data comparability expresses the confidence with which one data set can be compared to another. The datasets generated through the course of this project will be done so in accordance to a set methodology so that each phase is directly comparable to another. This allows for appropriate data comparison and identification of anomalies, if present. To ensure appropriate QA/QC standards, direct pressure, temperature, and logging measurements obtained through the proposed operations will be directly comparable to previously acquired data during the site characterization phase.

A.4.g Method Sensitivity

Table 10 through **Table 13** provide additional details on gauge specifications and sensitivities.

Table 10: Pressure and Temperature—Downhole Gauge Specifications

Parameter	Value
Calibrated working pressure range	200 psi to 10,000 psi
Initial pressure accuracy	+-0.015% (1.5 psi at full scale)
Pressure resolution	0.0001 psi
Pressure drift stability	2.0 psi per year at full scale
Calibrated working temperature range	77°F to 302°F (25°C to 150°C)
Initial temperature accuracy	0.27°F (0.15°C)
Temperature resolution	0.0001°F
Temperature drift stability	0.018°F (<0.01°C)
Max temperature	302°F

Table 11: Pressure Field Gauge – Wellhead Pressure/Temperature Gauge

Parameter	Value
Calibrated working pressure range	0-15,000 psi
Initial pressure accuracy	±0.03% FS
Pressure resolution	0.0003% FS
Pressure drift stability	<3
Calibrated working temperature range	-4ºF to 158ºF
Initial temperature accuracy	±0.09 ºF (0.5ºC)
Temperature resolution	0.02 ºF (0.01 ºC)
Max temperature	158ºF

Table 12: Leak Detection – Handheld Leak Detection Device

Parameter	Value
Calibrated working detection range	0 – 10,000 ppm CO_2
accuracy	±5% of reading or ±2% of full scale
Measurement resolution	20 ppm

Table 13: Mass Flow Rate Field Gauge – CO_2 Mass Flow Rate

Parameter	Value
Calibrated working flow rate range	2739.73-3561.64 tonne(Metric)/day
Initial mass flow rate accuracy	0.1000 (% rate)
Mass flow rate resolution	0.00
Mass flow rate drift stability	To be determined

A.5 Special Training/Certifications

A.5.a Specialized Training and Certifications

All sampling equipment and wireline logging tools will be operated by trained, qualified, and, where required, certified personnel according to the service company which provides the equipment. The subsequent data will be processed and analyzed according to industry standards. No specialized certifications are required for personnel conducting groundwater sampling, but field sampling will be conducted by trained personnel who understand and will follow the project specific sampling procedures. Upon request, MPC will provide the agency with all laboratory Standard Operating Procedures (SOPs) developed for the specific parameters using the appropriate standard methodologies. Each laboratory technician conducting analysis on the samples will be trained for the SOP developed for each standard method. MPC will include the technician's training certification with the biannual report.

A.5.b/c Training Provider and Responsibility

All personnel training will be will be provided by the operator or by the subcontractor responsible for the data collection activity.

A.6 Documentation and Records

Each monitoring focus area produces different types of data and has distinct data-management needs (input, storage, processing, manipulation, querying, access/output). In order to efficiently store and utilize this array of data, several databases under individual tasks (i.e. pressure monitoring) will be generated and maintained, depending on their compatibility with an overarching distributed data-management system. To the best degree possible, an attempt will be made to link these individual databases to a centralized database and file archive system. Monitoring data will be collected under the appropriate quality assurance protocols (e.g., compliance related data will have higher QA protocols than non-compliance related data). These various data sets will be acquired and manipulated into many different file-formats and data forms (hard copy, electronic image files, physically samples etc.). Each data type will require different data-management protocols and storage/management tools which may vary from simple file management to relational databases to geographic information systems.

Technical experts will screen, validate, and/or pre-process raw data to produce “interpretation-ready” or interpreted data sets. Data with different levels of quality assurance differeinations (e.g., legacy data vs compliance-driven data) and at different levels of processing/verification will be managed separately.

A.6.a Report Format and Package Information

A semi-annual report from MPC to EPA will contain all required project data, including testing and monitoring information as specified by the UIC Class VI permit. Data will be provided in electronic or other formats as required by the UIC Program Director.

A.6.b Other Project Documents, Records, and Electronic Files

Other documents, records, and electronic files such as well logs, test results, or other data will be provided as required by the UIC Program Director.

A.6.c/d Data Storage and Duration

MPC or a designated contractor will maintain the required project data as provided in the permit guidelines.

A.6.e QASP Distribution Responsibility

A representative from MPC will be designated as the responsible party for ensuring that all those on the distribution list will receive the most current copy of the approved QASP.

B. Direct Data Generation and Acquisition

B.1 Sampling Process Design

Discussion in this section is focused on groundwater and fluid sampling and does not address monitoring methods that do not gather physical samples (e.g., logging, seismic monitoring, and pressure/temperature monitoring). During the pre-injection and injection phases, groundwater sampling is planned to include an extensive set of chemical parameters to establish aqueous geochemical reference data. Parameters will include selected constituents that: (1) have primary and secondary EPA drinking water maximum contaminant levels, (2) are the most responsive to interaction with CO_2 or brine, (3) are needed for quality control, and (4) may be needed for geochemical modeling. After a sufficient baseline is established, monitoring scope may shift to a subset of indicator parameters that are (1) the most responsive to interaction with CO_2 or brine and (2) are needed for quality control to accurately test for and monitor the presence (or lack thereof) of CO_2 migration. Implementation of a reduced set of parameters would be done in consultation with the UIC Program Director. During any period where a reduced set of analytes is used, if statistically significant trends are observed that are the result of unintended CO_2 or brine migration, the analytical list would be expanded to the full set of monitoring parameters. Groundwater samples taken from the Eutaw and Wilcox aquifer zones will be analyzed using a laboratory meeting the requirements under the EPA Environmental Laboratory Accreditation Program. All other samples will be analyzed by the operator or a third party laboratory. Dissolved CO_2 will be analyzed by methods consistent with Test Method B of ASTM D 513-06, “Standard Test Methods for Total and Dissolved Carbon Dioxide in Water” or equivalent.

B.1.a Design Strategy

CO_2 Stream Monitoring Strategy

The primary purpose of analyzing the CO_2 stream is to evaluate the potential interactions of carbon dioxide and/or other constituents of the injectate with formation solids and fluids. This analysis can also identify (or rule out) potential interactions with well materials. Establishing the chemical composition of the injectate also supports the determination of whether the injectate meets the qualifications of hazardous waste under the Resource Conservation and Recovery Act (RCRA)[1] and/or the Comprehensive Environmental Response, Compensation, and Liability Act, (CERCLA)[2]. Additionally, monitoring the chemical and physical characteristics of the carbon dioxide may help distinguish the injectate from the native fluids and gases if unintended leakage from the storage reservoir occurred. Injectate monitoring is required at a sufficient frequency to detect changes to any physical and chemical properties that may result in a deviation from the permitted specifications. Calibration of equipment used to monitor pressures, temperatures, and flow rates of CO_2 into the injection well at the injection well and at the verification well shall be conducted annually. Reports shall contain test equipment used for calibration, including test equipment manufacturers, model numbers, serial numbers, calibration dates and expiration dates.

Corrosion Monitoring Strategy

Corrosion coupon analyses will be conducted quarterly to aid in ensuring the mechanical integrity of the equipment in contact with the carbon dioxide. Coupons shall be sent out quarterly for analysis and an analysis will be conducted in accordance with NACE Standard RP-0775 (or similar) to determine and document corrosion wear rates based on mass loss.

[1] Resource Conservation and Recovery Act (RCRA), 42 U.S.C. 6901 et seq. (1976)
[2] Comprehensive Environmental Response, Compensation, and Liability Act, (CERCLA) 42 U.S.C. 9601 et seq. (1980).

Shallow Groundwater Monitoring Strategy

Seven monitoring wells have been selected for shallow groundwater monitoring in the Kemper County Storage Complex (**Figure 1**). These wells will be installed and screened in the Eocene-aged Middle/Lower Wilcox group, which serve as the primary private water well sources in the area. The wells were selected to give a representative spatial distribution around the planned CO_2 injection wells and modeled plume development.

Deep Groundwater Monitoring Strategy

Seven deep groundwater monitoring wells will be completed in the Upper Cretaceous Eutaw Formation (**Figure 1**). These wells will serve to detect any early leakage in the closest freshwater aquifer in the subsurface above the injection zone. Fluid sampling at the deep groundwater wells will be used to determine if leakage is occurring at or near the injection wells. In addition to baseline sample collection and analysis prior to the start of injection, pres fluid samples will be collected from these seven deep USDW monitoring wells during the injection phase. Mechanical Integrity Testing and downhole temperature monitoring at the injection wells will also provide data to ensure the mechanical integrity of the well is maintained. With the planned sampling and monitoring frequencies, baseline conditions will be documented, natural variability in conditions will be characterized, unintended brine or CO_2 leakage would be detected, and sufficient data will be collected to demonstrate that the effects of CO_2 injection are limited to the intended storage reservoir.

B.1.b Sampling Site Contingency

The monitoring wells are located on MPC property and access permissions have already been granted. No problems of site inaccessibility are anticipated. If inclement weather makes site access difficult, sampling schedules will be revised and alternative dates may be selected that would still meet permit-related conditions.

B.1.c Critical/Informational Data

During both groundwater sampling and analytical efforts, detailed field and laboratory documentation will be taken. Documentation will be recorded in field and laboratory forms and notebooks. Critical information will include time and date of activity, person(s) performing activity, location of activity (well-field sampling) or instrument (lab analysis), field or laboratory instrument calibration data, field parameter values. For laboratory analyses, much of the critical data are generated during the analysis and provided to end users in digital and printed formats. Noncritical data may include appearance and odor of the sample, problems with well or sampling equipment, and weather conditions.

B.1.d Sources of Variability

Potential sources of variability related to monitoring activities include (1) natural variation in fluid quality, formation pressure and temperature and seismic activity; (2) variation in fluid quality, formation pressure and temperature due to project operations; (3) changes in recharge due to precipitation amount; (4) changes in instrument calibration during sampling or analytical activity; 5) different staff collecting or analyzing samples; (6) differences in environmental conditions during field sampling activities; (7) changes in analytical data quality during life of project; and (8) data entry errors related to maintaining project databases.

Checks and balances to eliminate, reduce, or reconcile variability related to monitoring activities include (1) collecting long-term baseline data to observe and document natural variation in monitoring parameters, (2) evaluating data in a timely manner after collection to observe anomalies in data that can be addressed, be resampled or reanalyzed, (3) conducting statistical analysis of monitoring data to determine whether variability in a data set is the result of project activities or natural variation, (4) maintaining weather-related data using on-site weather monitoring data or data collected near project site (such as from local airports), (5) checking instrument calibration before, during and after sampling or sample analysis, (6) thoroughly training staff, (7) conducting laboratory quality assurance checks using third party reference materials, and/or blind and/or duplicate sample checks, and (8) developing a systematic review process of data that can include sample-specific data quality checks (i.e., cation/anion balance for aqueous samples).

B.2 Sampling Methods

B.2.a/b Sampling SOPs

Groundwater samples will be collected primarily using a low-flow sampling method consistent with ASTM D6452-99 [3] or Puls and Barcelona [4]. If a flow-through cell is not used, field parameters will be measured in grab samples. Groundwater wells will be purged to ensure samples are representative of formation water quality. Static water levels in each well will be determined using an electronic water level indicator before any purging or sampling activities begin. Dedicated pumps (e.g., bladder pumps) will be installed in each monitoring well to minimize potential cross contamination between wells. Groundwater pH, temperature, specific conductance, and dissolved oxygen will be monitored in the field using portable probes and a flow-through cell consistent with standard methods [5] given sufficient flow rates and volumes. Field chemistry probes will be calibrated at the beginning of each sampling day according to equipment manufacturer procedures using standard reference solutions. When a flow-through cell is used, field parameters will be continuously monitored and will be considered stable when three successive measurements made three minutes apart meet the criteria listed in **Table** 14.

Table 14: Stabilization Criteria of Water Quality Parameters During Shallow Well Purging

Field Parameter	Stabilization Criteria
pH, temperature, specific conductance, dissolved oxygen, turbidity	*parameter measurement until ±10% value stabilization

*exact parameter stabilization threshold will depend on which purge method is slelected from ASTM DX

[3] ASTM, 2005, Method D6452-99 (reapproved 2005), *Standard Guide for Purging Methods for Wells Used for Ground-Water Quality Investigations*, ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA

[4] Puls, R W, and Barcelona, M J. *Ground water issue: Low-flow (minimal drawdown) ground-water sampling procedures*. United States: N. p., 1996. Web.

[5] APHA, 2005, Standard methods for the examination of water and wastewater (21st edition), American Public Health Association, Washington, DC.

After field parameters have stabilized, samples will be collected. Samples requiring filtration will be filtered through 0.45 µm flow-through filter cartridges as appropriate and consistent with ASTM D6564- 00. Prior to sample collection, filters will be purged with a minimum of 100 mL of well water (or more if required by the filter manufacturer). For alkalinity and total CO_2 samples, efforts will be made to minimize exposure to the atmosphere during filtration, collection in sample containers, and analysis.

B.2.c In-situ Monitoring

Monitoring of groundwater chemistry in situ is not planned at this time. Monitoring of groundwater chemistry within and above the injection zone will be performed as described in **Section F.** of the *Testing and Monitoring Plan*.

B.2.d Continuous Monitoring

Pressure data will be collected from In-zone and Above-zone monitoring wells periodically, whether hourly or daily, using dedicated pressure transducers with data loggers.

B.2.e Sample Homogenization, Composition, Filtration

Described in Section B.2.b.

B.2.f Sample Containers and Volumes

All samples will be collected in new containers using industry accepted standards and practices. Container type and size for each sample type are listed in **Table 15** and **Table 16**.

Table 15: Summary of Sample Containers, Preservation Treatments, and Holding Times for CO_2 Gas Stream Analysis

Sample	Volume/Container Material	Preservation Technique	Sample Holding time (max)
CO_2 gas stream	(2) 2L MLB Polybags (1) 75 cc Mini Cylinder	Sample Storage Cabinets	5 Business Days

Table 16: Summary of Anticipated Sample Containers, Preservation Treatments, and Holding Times for Ground Water Samples

Target Parameters	Volume/Container Material	Preservation Technique	Sample Holding Time
Cations: Ca, Fe, K, Mg, Na, Si, Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb Se, Tl	250 ml/HDPE	Filtered, nitric acid, cool 4°C	60 days
Dissolved CO_2	2 × 60 ml/HDPE	Filtered, cool 4°C	14 days
Isotopes: 3H, δD, δ18O, δ34S, and δ13C	2 × 60 ml/HDPE	Filtered, cool 4°C	4 weeks
Isotopes: δ34S	250 ml/HDPE	Filtered, cool 4°C	4 weeks
Isotopes: δD, δ18O, δ13C	60 ml/HDPE	Filtered, cool 4°C	4 weeks
Alkalinity, anions (Br, Cl, F, NO3, SO4)	500 ml/HDPE	Filtered, cool 4°C	45 days
Field Confirmation: Temperature, dissolved oxygen, specific conductance, pH	200 ml/glass jar	None	< 1 hour
Field Confirmation: Density	60 ml/HDPE	Filtered	< 1 hour

B.2.g Sample Preservation

Sample preservation methods are outlined in **Table 15** and Error! Reference source not found..

B.2.h Cleaning/Decontamination of Sampling Equipment

Pumps will be installed in each ground water monitoring well in order to mitigate potential cross contamination among wells. Each installed pump will remain in the well for the duration of the project period except for maintenance or replacement. The pumps will be cleaned on the outside before installation with a non-phosphate detergent. The pump will then be rinsed appropriately with deionized water. 1 L of deionized water will be cycled through the pump and along with tubing. Individual prepared pumps and tubing will be placed in clean containers for transport to the field for installation. All sampling glassware (such as pipets, beakers, filter holders, etc.) will be cleaned using tap water, and then washed in a dilute nitric acid solution, before being thorougly rinsed with deionized water prior to use.

B.2.i Support Facilities

The following tools may be needed to sample groundwater: generator, vacuum pump, compressor, multi-electrode water quality sonde, and various meters to take analytical measurements such as pH and electrical conductance. Analytical field activities may take place in field vehicles and/or portable on site trailers. Well gauges used for verification will be handled using industry standard best practices and pocedures recommended from the vendor.

B.2.j Corrective Action, Personnel, and Documentation

Properly testing equipment and implementing corrective actions on broken or malfunctioning field equipment will be the responsibility of field personnel. If corrective action is not possible in the field, then equipment will be sent back to the manufacturer or qualified technician to be repaired, serviced, or replaced. Corrective actions significant enough to affect analytical data will be noted and documented. In the event that defective equipment will cause disruptions to the sampling schedule, revisions will be made and communicated with the UIC Program Director.

B.3 Sample Handling and Custody

Sample handling and hold times will be congruent with US EPA (1974), and ASTM Method D6517-00 (2005). Once collected, samples will be placed in coolers with ice to be maintained to a temperature of approximately 4 degrees celcius until analyzed. Samples will be sent for laboratory analysis within 24 hours. Additional/alternative sample practices may be used at the request of the Director to meet all analytical needs. See **Table 15** and Error! Reference source not found..

B.3.a Maximum Hold Time/Time Before Retrieval

See **Table 15** and Error! Reference source not found..

B.3.b Sample Transportation

Samples will be transported in coolers with ice maintained to approximately 4 degrees celcius and sent to approved laboratory within 24 hours of sampling.

B.3.c Sampling Documentation

Detailed notes will be taken in the field by personnel while goundwater samples are collected. Notes will be archived for later reference.

B.3.d Sample Identification

Each groundwater sample container will have a label with the following information: project name/number, sample date and location, sample ID number, fresh or brine water, volume taken, analyte, filtration used (if applicable), and preservative used (if any).B.3.e. Sample Chain-of-Custody.

Chain of custody for all groundwater samples will documented using a standard form populated by sampling personnel. Copies of this form will be provided to laboratory personnel upon delivery of groundwater samples for analysis. These forms will be archived for future reference.

B.4 Analytical Methods

B.4.a Analytical SOPs

Analytical SOPs are referenced in **Table 4** through **Table 7**. Other laboratory specific SOPs utilized by the laboratory will be determined after a contract laboratory has been selected. Upon request MPC will provide the agency with all laboratory SOPs developed for the specific parameter using the appropriate standard method. Each laboratory technician conducting the analysis on the samples will be trained on the SOP developed for each standard method. MPC will include the technician's training certification with the biannual report.

B.4.b Equipment/Instrumentation Needed

Equipment and instrumentation is specified in the individual analytical methods referenced in **Table 4** through **Table 7.**

B.4.c Method Performance Criteria

Nonstandard method performance criteria are not anticipated for this project.

B.4.d Analytical Failure

Each laboratory conducting the analyses in **Table 3** through **Taable 8** will be responsible for appropriately addressing analytical failure according to their individual SOPs.

B.4.e Sample Disposal

Each laboratory conducting the analyses in **Table 3** through **Table 8** will be responsible for appropriate sample disposal according to their individual SOPs.

B.4.f Laboratory Turnaround

Laboratory turnaround will vary by laboratory, but generally turnaround of verified analytical results within two months will be suitable for project needs.

B.4.g Method Validation for Nonstandard Methods

Nonstandard methods are not anticipated for this project. If nonstandard methods are needed or proposed in the future, the EPA will be consulted on additional appropriate actions to be taken.

B.5 Quality Control

B.5.a QC activities

Blanks

For shallow groundwater sampling, a field blank will be collected and analyzed for the inorganic analytes in **Table 3** and **Table 4** at a frequency of 10% or greater. Field blanks will be exposed to the same field and transport conditions as the groundwater samples. Blanks will also be utilized for deep groundwater sampling and analyzed for the inorganic analytes in **Table 3** and **Table 4** at a frequency of 10% or greater. Field blanks will be used to detect contamination resulting from the collection and transportation process.

Duplicates

For each shallow groundwater sampling round, a duplicate groundwater sample is collected from a well from a rotating schedule. Duplicate samples are collected from the same source immediately after the original sample in different sample containers and processed as all other samples. Duplicate samples are used to assess sample heterogeneity and analytical precision.

B.5.b Exceeding Control Limits

If the sample analytical results exceed control limits (i.e., ion balances > ±10%), further examination of the analytical results will be done by evaluating the ratio of the measured total dissolved solids (TDS) to the calculated TDS (i.e., mass balance) per APHA method. The method indicates which ion analyses should be considered suspect based on the mass balance ratio. Suspect ion analyses are then reviewed in the context of historical data and interlaboratory results, if available. Suspect ion analyses are then brought to the attention of the analytical laboratory for confirmation and/or reanalysis. The ion balance is recalculated, and if the error is still not resolved, suspect data are identified and may be given less importance in data interpretations.

B.5.c Calculating Applicable QC Statistics

Charge Balance

The analytical results are evaluated to determine correctness of analyses based on anion-cation charge balance calculation. Because all potable waters are electrically neutral, the chemical analyses should yield equally negative and positive ionic activity. The anion-cation charge balance will be calculated using the formula:

$$\%\ difference\ =\ 100 * \frac{\sum cations - \sum anions}{\sum cations + \sum anions}$$

where the sums of the ions are represented in milliequivalents (meq) per liter and the criteria for acceptable charge balance is ±10%.

Mass Balance

The ratio of the measured TDS to the calculated TDS will be calculated in instances where the charge balance acceptance criteria are exceeded using the formula: 1.0 < $measured\ TDS\ calculated\ TDS$ < 1.2, where the anticipated values are between 1.0 and 1.2.

Outliers

A determination of one or more statistical outliers is essential prior to the statistical evaluation of groundwater. This project will use the EPA's Unified Guidance[6] as a basis for selection of recommended statistical methods to identify outliers in groundwater chemistry data sets as appropriate. These techniques include Probability Plots, Box Plots, Dixon's test, and Rosner's test. The EPA-1989 outlier test may also be used as another screening tool to identify potential outliers.

B.6 Instrument/Equipment Testing, Inspection, and Maintenance

Logging tool equipment will be maintained as per wireline industry best practices. For groundwater sampling, field equipment will be maintained, factory serviced, and factory calibrated per manufacturer's recommendations. Spare parts that may be needed during sampling will be included in supplies on-hand during field sampling. For laboratory equipment, all testing, inspection, and maintenance will be the responsibility of the analytical laboratory per standard practice, method-specific protocol, or other official requirement.

B.7 Instrument/Equipment Calibration and Frequency

B.7.a Calibration and Frequency of Calibration

Pressure/temperature gauge calibration information is located in **Table 10** and **Table 11.** Logging tool calibration will be at the discretion of the service company providing the equipment, following standard industry practices. Calibration frequency will be determined by standard industry practices. For groundwater sampling, portable field meters or muliprobe sondes used to determine field parameters (e.g., pH, temperature, specific conductance, dissolved oxygen) are calibrated according to manufacturer recommendations and equipment manuals (Hach, 2006) each day before sample

[6] U.S. Environmental Protection Agency (US EPA), 2009, Statistical analysis of groundwater monitoring data at RCRA facilities—Unified Guidance, US EPA, Office of Solid Waste, Washington, DC.

collection begins. Recalibration is performed if any components yield atypical values or fail to stabilize during sampling.

B.7.b Calibration Methodology

Logging tool calibration methodology will follow standard industry practices in For groundwater sampling, standards used for calibration are typically 7 and 10 for pH, a potassium chloride solution yielding a value of 1413 microseimens per centimeter (µS/cm) at 25°C for specific conductance, and a 100% dissolved O_2 solution for dissolved oxygen. Calibration is performed for the pH meters per manufactuer's specifications using a 2-point calibration bounding the range of the sample. For coulometry, sodium carbonate standards (typically yielding a concentration of 4,000 mg CO_2/L) are routinely analyzed to evaluate instrument.

B.7.c Calibration Resolution and Documentation

Logging tool calibration resolution and documentation will follow standard industry practices in. For groundwater sampling, calibration values are recorded in daily sampling records and any errors in calibration are noted. For parameters where calibration is not acceptable, redundant equipment may be used so loss of data is minimized.

B.8 Inspection/Acceptance for Supplies and Consumables

B.8.a/b Supplies, Consumables, and Responsibilities

Supplies and consumables for field and laboratory operations will be procured, inspected, and accepted as required from vendors approved by MPC or the respective subcontractor responsible for the data collection activity. Acquisition of supplies and consumables related to groundwater analyses will be the responsibility of the laboratory per established standard methodology or operating procedures.

C. Indirect Data Measurements

C.1 Data Aquisition

C.1.a Data Sources

For in-zone pressure monitoring, the in-zone pressure gauges placed within the identified monitoring wells will be used to gather pressure data. In-zone monitoring wells are shown in **Figure 1**.

C.1.b Relevance to Project

In-zone pressure monitoring data will be used in numerical modeling to predict plume and pressure front behavior and confirm the plume stage within the AoR.

C.1.c Acceptance Criteria

Gauges and other equipment used to collect non-direct measurements will be checked periodically and maintained according to manufacturer recommendations for equipment care and operation, to ensure the accuracy of readings as they are incorporated into the model.

C.1.d Resources/Facilities Needed

MPC will subcontract all necessary resources and facilities for the in-zone pressure monitoring and groundwater sampling.

C.1.e Validity Limits and Operating Conditions

All date incorporated into numerical models will be vetted using procedural checks and balances that are designed to ensure the accuracy of the analysis being conducted.

C.2 Data Management

C.2.a Data Management Scheme

MPC or a designated contractor will maintain the required project data as provided elsewhere in the permit. Data will be backed up on tape or held on secure servers.

C.2.b Recordkeeping and Tracking Practices

All records of gathered data will be securely held and properly labeled for auditing purposes.

C.2.c Data Handling Equipment/Procedures

All equipment used to store data will be properly maintained and operated according to proper industry techniques. MPC will ensure that all necessary supervisory control and data acquisition (SCADA) systems and vendor data acquisition systems will interface with one another and that all subsequent data will be held on a secure server.

C.2.d Responsibility

The primary project managers will be responsible for ensuring proper data management is maintained.

C.2.e Data Archival and Retrieval

All data will be held by MPC and will be maintained and stored for auditing purposes as described in section 3.2.3

C.2.f Hardware and Software Configurations

All MPC and vendor hardware and software configurations will be appropriately interfaced.

C.2.g Checklists and Forms

Checklists and forms will be procured and generated as necessary.

D. Assessment and Oversight

D.1 Assessments and Response Actions

D.1.a Activities to be Conducted

Please refer to **Table 2** in section A.3.a/b. for a summary of groundwater quality sample collection frequency. After completion of sample analysis, results will be reviewed for QC criteria as noted in section B.5. If the data quality fails to meet the established criteria, samples will be reanalyzed if still within holding time criteria. If outside of holding time criteria, additional samples may be collected or sample results may be excluded from data evaluations and interpretations. Evaluation for data consistency will be performed according to procedures described in the EPA 2009 Unified Guidance[7].

D.1.b Responsibility for Conducting Assessments

Organizations gathering data will be responsible for conducting their internal assessments. All stop work orders will be handled internally within individual organizations.

D.1.c Assessment Reporting

All assessment information should be reported to the individual organizations project manager outlined in A.1.a/b.

D.1.d Corrective Action

All corrective action affecting only an individual organization's data collection responsibility should be addressed, verified, and documented by the individual project managers and communicated to the other project managers as necessary. Corrective actions affecting multiple organizations should be addressed by all members of the project leadership and communicated to other members on the distribution list for the QASP. Assessments may require integration of information from multiple monitoring sources across organizations (operational, in-zone monitoring, above-zone monitoring) to determine whether correction actions are required and/or the most cost-efficient and effective action to implement. MPC will coordinate multiorganization assessments and corrective actions as warranted.

D.2 Reports to Management

D.2.a/b QA Status Reports

QA status reports should not be needed. If any testing or monitoring techniques are changed, the QASP will be reviewed and updated as appropriate in consultation with

[7] U.S. Environmental Protection Agency (US EPA), 2009, Statistical analysis of groundwater monitoring data at RCRA facilities—Unified Guidance, US EPA, Office of Solid Waste, Washington, DC.

the UIC Program Director. Revised QASPs will be distributed by MPC to the full distribution list identified at the beginning of this document.

E. Data Validation and Usability

E.1 Data Review, Verification, and Validation

E.1.a Criteria for Accepting, Rejecting, or Qualifying Data

Groundwater quality data validation will include the review of the concentration units, sample holding times, and the review of duplicate, blank and other appropriate QA/QC results. All groundwater quality results will be entered into a database or spreadsheet with periodic data review and analysis. MPC will retain copies of the laboratory analytical test results and/or reports. Analytical results will be reported on a frequency based on the approved UIC permit conditions. In the periodic reports, data will be presented in graphical and tabular formats as appropriate to characterize general groundwater quality and identify intrawell variability with time. After sufficient data have been collected, additional methods, such as those described in the EPA 2009 Unified Guidance[8] will be used to evaluate intrawell variations for groundwater constituents, to evaluate if significant changes have occurred that could be the result of CO_2 or brine seepage beyond the intended storage reservoir.

E.2 Verification and Validation Methods

E.2.a Data Verification and Validation Processes

See Section D.1.a. and Section B.5.

For the purposes of determining data consistency, appropriate statistical software will be utilized.

[8] U.S. Environmental Protection Agency (US EPA), 2009, Statistical analysis of groundwater monitoring data at RCRA facilities—Unified Guidance, US EPA, Office of Solid Waste, Washington, DC.

E.2.b Data Verification and Validation Responsibility

MPC or its designated subcontractor will verify and validate groundwater sampling data.

E.2.c Issue Resolution Process and Responsibility

MPC or its designated Coordinator will overview the groundwater data handling, management, and assessment process. Staff involved in these processes will consult with the Coordinator to determine actions required to resolve issues.

E.2.d Checklist, Forms, and Calculations

Checklists and forms will be developed specifically to meet permit requirements. **Table 17** provides an example of the type of information used for data verification of groundwater quality data.

Table 17: Example table of criteria used to evaluate data quality

MVA ID	Anion charge	Cation charge	Charge balance	CB rating	Calculated TDS	Measured TDS	TDS Ratio	TDS Rating
ICCS_10B_01A	14.4	13.60	-2.84	pass	760.50	785	1.0	pass

E.3 Reconciliation with User Requirements

E.3.a Evaluation of Data Uncertainty

Statistical software will be used to determine groundwater data consistency using methods consistent with EPA 2009 Unified Guidance.[9]

E.3.b Data Limitations Reporting

MPC will use the current operating procedure on the use, sharing, and presentation of results and/or data for the Kemper County Storage Complex project. This

[9] U.S. Environmental Protection Agency (US EPA), 2009, Statistical analysis of groundwater monitoring data at RCRA facilities—Unified Guidance, US EPA, Office of Solid Waste, Washington, DC.

procedure has been developed to ensure quality, internal consistency and facilitate tracking and record keeping of data end users and associated publications. The designated project managers will be responsible for ensuring that data developed by their respective organizations is presented with the appropriate data-use limitations.